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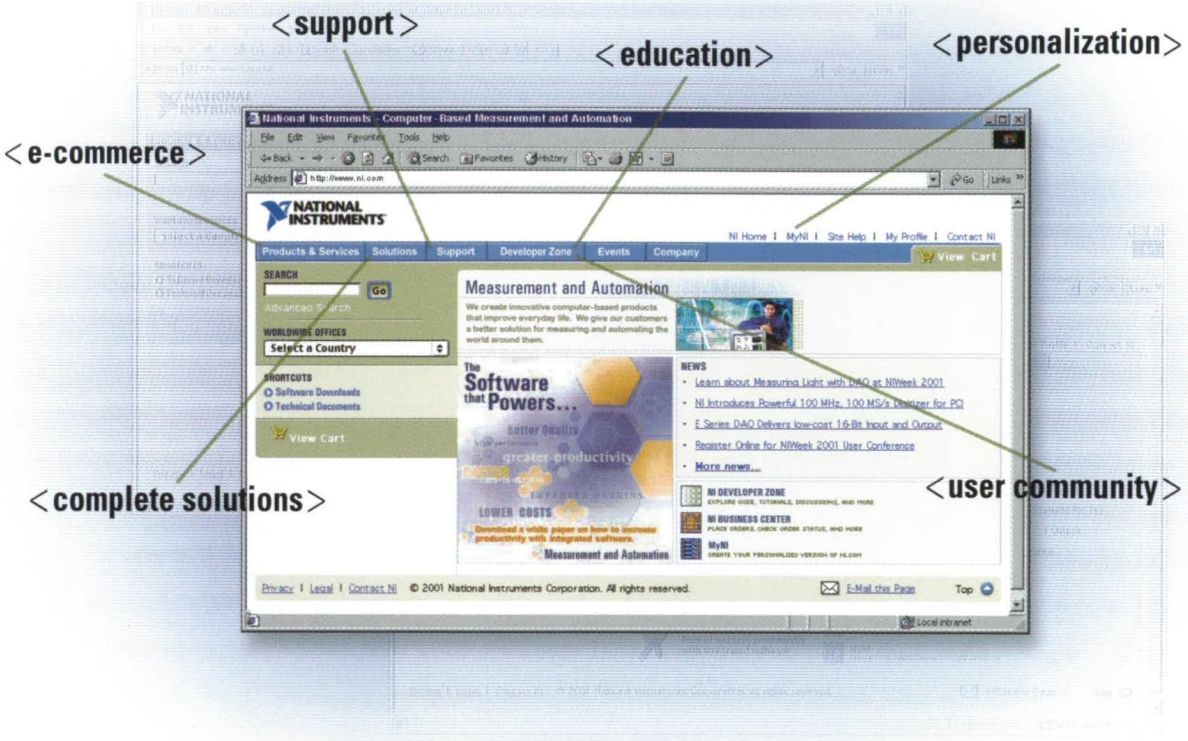

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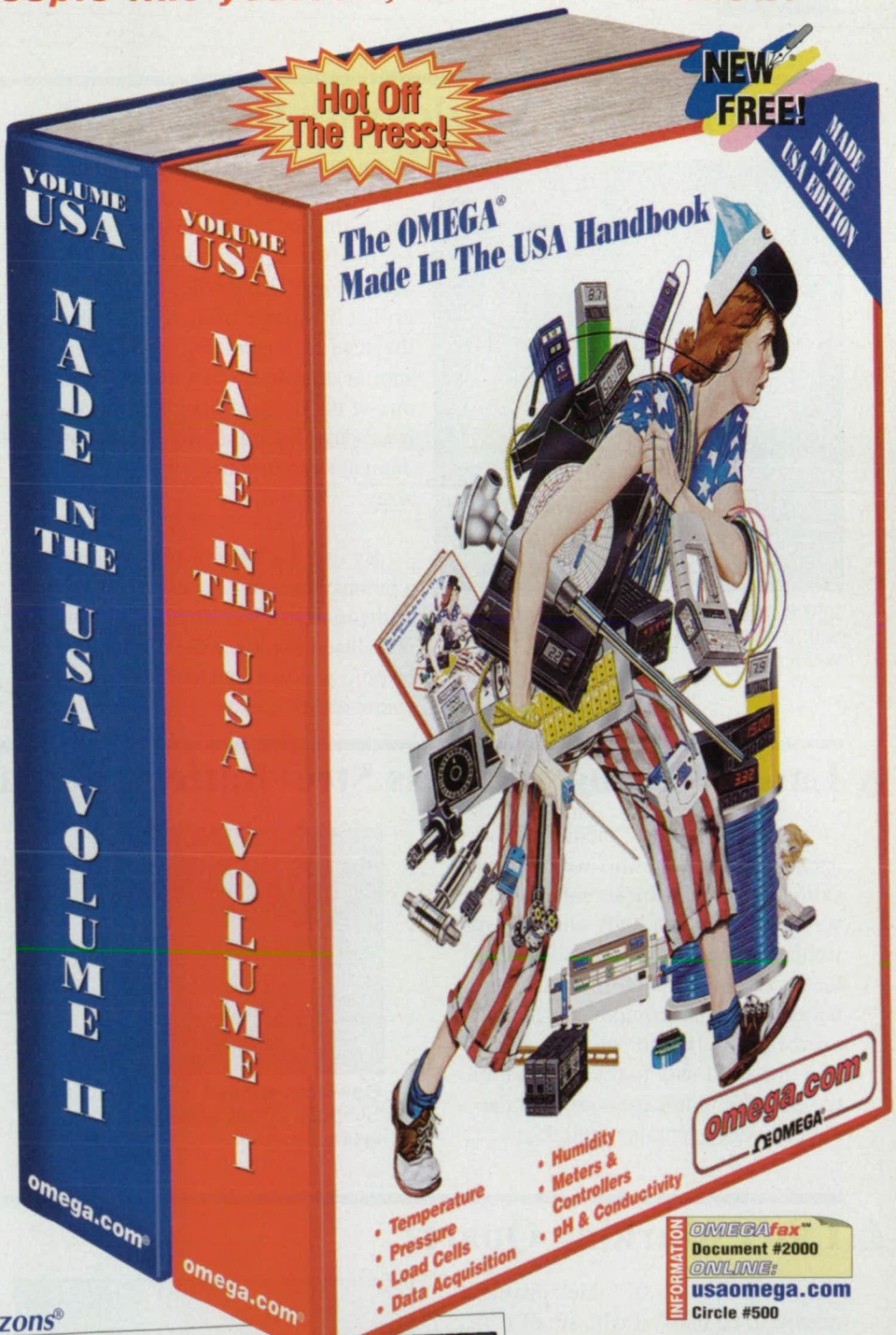

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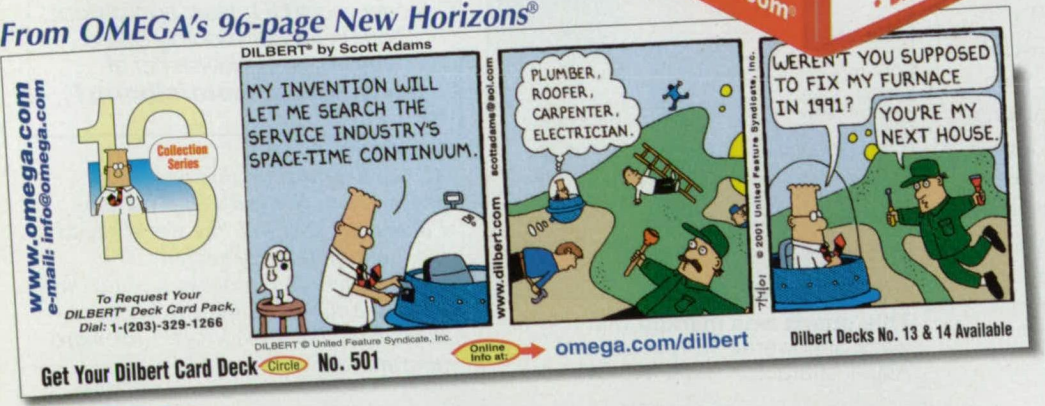

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CO_2 Laser Applications of the Month

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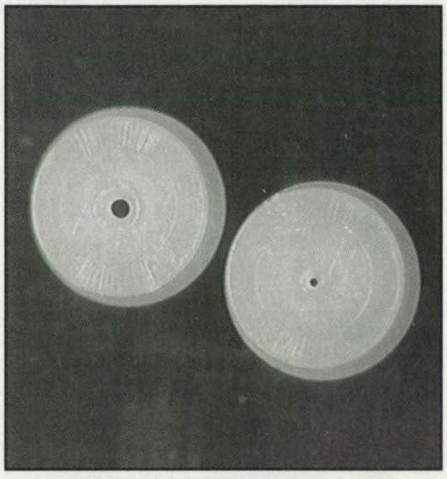
Drilling Plastic Nozzles with CO_2 Lasers



250 & 100 micron hole sizes drilled with a Synrad 48-2 CO_2 laser with 20 watts of power.

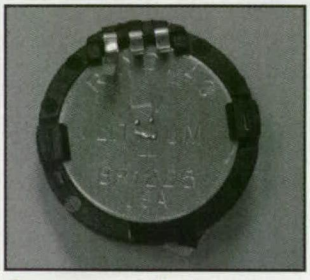
Lasers excel at drilling small holes (<0.01" in diameter). In fact, in most cases, the smaller the diameter, the better, down to a minimum size of about 50 microns. These holes can be directly drilled in a range of materials without the need for trepanning, resulting in shorter drilling times and highlighting one of the unique characteristics of the laser - one laser and one focused spot diameter can produce a range of hole sizes.

By using a burst or train of pulses, a precise amount of energy is delivered to the material. The final hole diameter will depend on the plastic's inherent heating and wavelength absorption characteristics, as well as the gas pressure used, and size of the focused beam. The number of pulses, duration of the pulse, and pulse frequency also enter into the equation. Small diameter increases can be made by altering the pulse numbers, larger ones by changing pulse duration and/or frequency. Changing the power is optional, and in many cases, the power input can be held at a constant value.

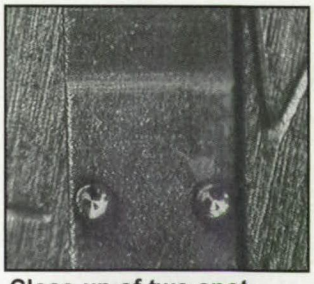
The plastic nozzles in the photo to the left were drilled with a Synrad sealed CO_2 laser. The focused spot size of the laser was around 200 microns, but hole diameters ranged from 75 to over 300 microns. The use of additional pulse power can be used to enlarge the hole by conduction effects.

Laser Welding Stainless Steel Battery Contacts

The fine control of the laser is once again highlighted in this welding application. The 0.01"-thick contact was welded to the main body with two spot welds. The spot welds provide excellent strength, while ensuring that the battery's internal components are not overheated during the process. In addition, the weld only partially penetrates the underlying thickness, so that the battery casing remains sealed.



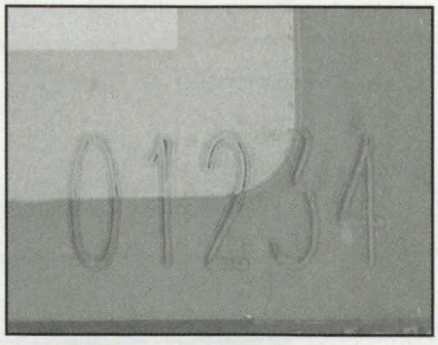
Contacts welded with Synrad's 200W sealed CO_2 laser.



Close-up of two spot welds.

Laser Marking Quartz

This piece of 0.01"-thick quartz needed to be marked with small alphanumeric characters. Because of the thin size of the test sample, problems with heat build-up and cracking could have potentially affected the results of the application. However, by careful selection of laser parameters - not only speed and power, but resolution, font and character spacing - a highly readable mark was produced.



This quartz was marked with only 5 watts of power at 15" per second. Actual character height is 0.04".

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All applications on this page were processed at ***Synrad's Applications Laboratory****. Synrad, the world's leading manufacturer of sealed CO_2 lasers, offers free process evaluations to companies with qualified applications. Call 1-800-SYNRAD1 for more information.*

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April 2002 • Vol. 26 No. 4

FEATURES

SOLUTIONS

22

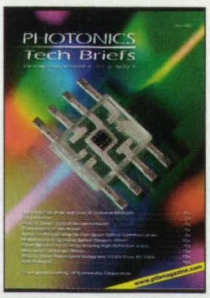
27

77

DEPARTMENTS

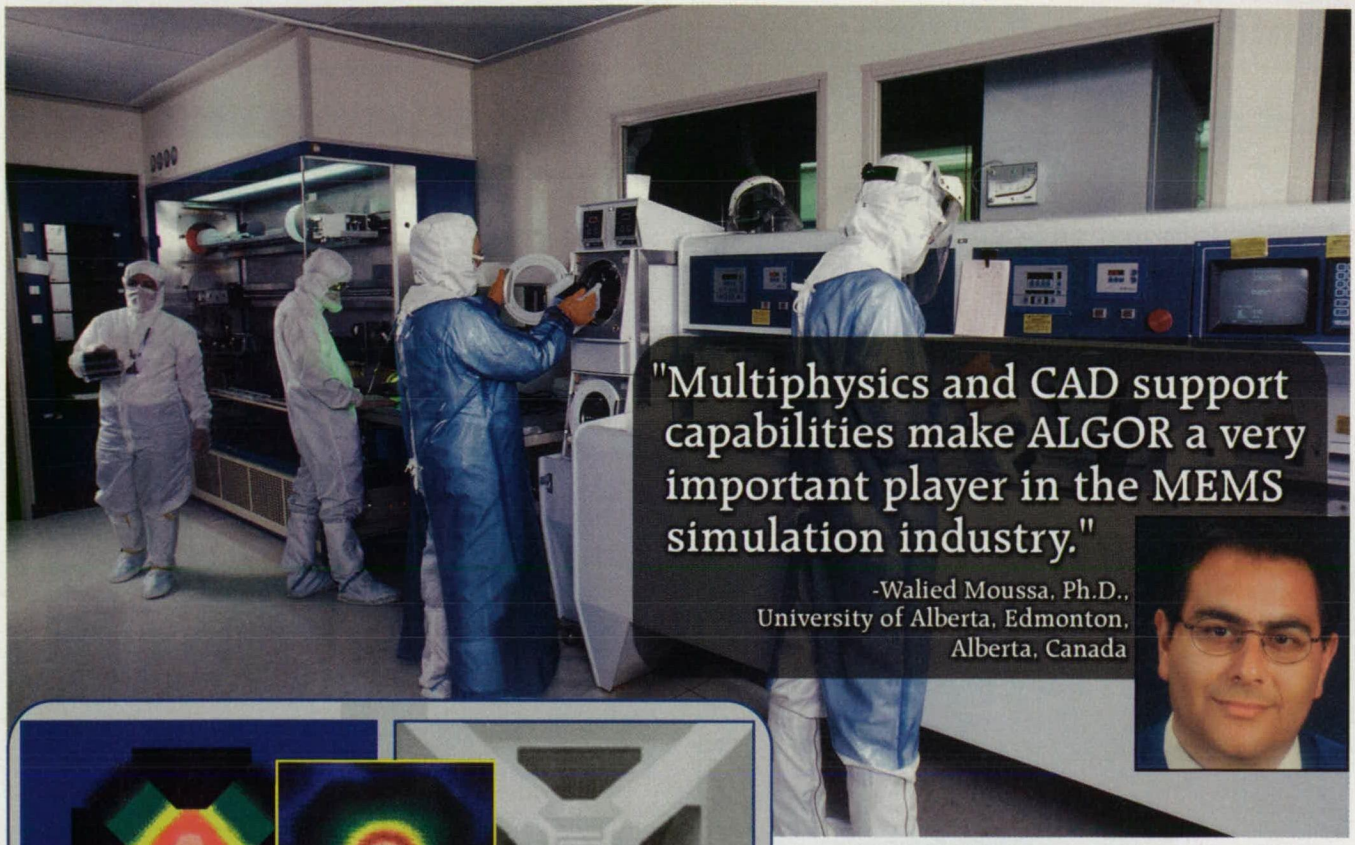
NEW FOR DESIGN ENGINEERS

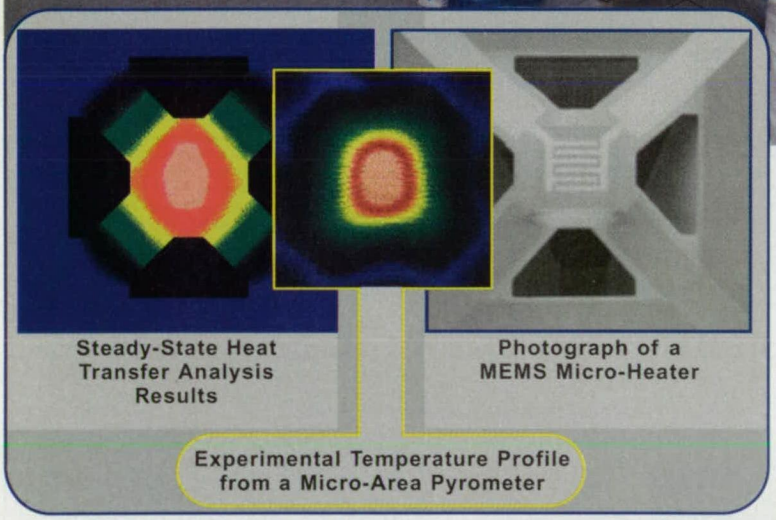
SPECIAL SUPPLEMENT



1a - 14a
Photonics Tech Briefs

Follows page 42 in selected editions only.





University faculty and students are using ALGOR FEA software in their studies of MEMS devices. In one recent experiment, university faculty collaborated with ALGOR on an experimental automotive gas sensor. Through research like this, the NINT helps develop MEMS for industry use.

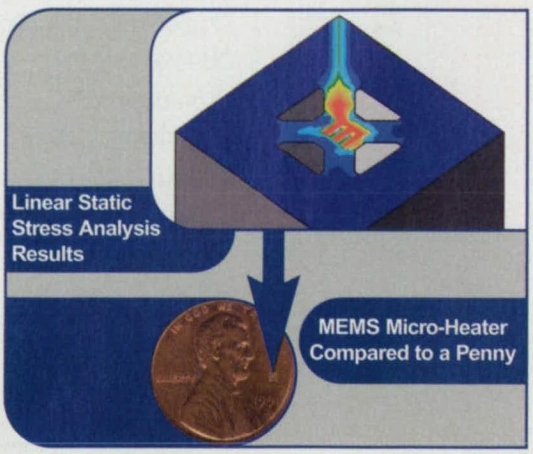
THE CHALLENGE: To design a MEMS micro-heater for an automotive gas sensor array that can withstand high temperatures. Automotive gas sensor arrays make engines burn more efficiently by sampling and adjusting combustion gasses. Each sensor functions at a unique temperature, which is controlled by a micro-heater. Simulating the thermal stresses for the MEMS device is critical to ensuring its performance.

THE SOLUTION: A finite element heat transfer analysis was performed on the micro-heater and the resulting maximum temperature agreed with experimental results published in Sensors and Actuators by Yaowu Mo, et. al. A linear stress analysis was then performed using the heat transfer analysis results to calculate the thermal expansion and stresses, which were high on the top surface near the center where the micro-heater attaches to the sensor. These results, which could not be easily obtained experimentally, indicate the need to optimize the sensor geometry to reduce the thermal stresses. Thus, engineers could optimize the design without creating expensive prototypes.

For this complete story and others, visit memsresearch.ALGOR.com

Leading MEMS Researcher Collaborated with ALGOR to Advance Automotive MEMS Research

The University of Alberta is a leader in the field of Micro Electro Mechanical Systems (MEMS) and future home of the Canadian National Institute for Nanotechnology (NINT), a $120 million, 180,000-sq. ft. research facility. NINT will support MEMS research with internship programs and by making its laboratory and production facilities accessible to other organizations.



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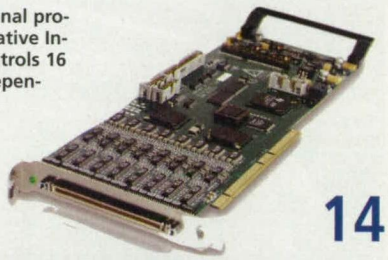
Contents *continued*

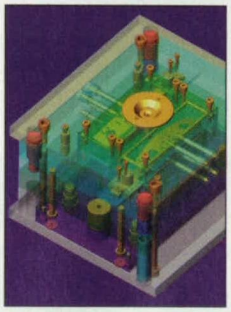
PRODUCT OF THE MONTH

The Toro analog I/O digital signal processing (DSP) card from Innovative Integration (Simi Valley, CA) controls 16 simultaneous channels of independent A/D and D/A conversion.



14

ON THE COVER



This full mold design was completed using SolidWorks and IMOLD for SolidWorks, a mold engineering solution from Manusoft Corp., Waconia, MN, that lets SolidWorks users design plastic injection molds. IMOLD for SolidWorks creates 3D, solids-based, parametric mold bases from vendor standards, and provides automatic pocketing for screws, pins, and bushings. For more information on this and other new products, see New on the Market on page 77.

(Image courtesy of Manusoft Corp.)

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If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

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Dryden Flight Research Center
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Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Remote Sensing; Command.
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Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
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merle.mckenzie@jpl.nasa.gov

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Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
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(281) 483-3809
commercialization@jsc.nasa.gov

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Selected technological strengths: Fluids and Fluid Systems; Materials Evaluation; Process Engineering; Command, Control and Monitor Systems; Range Systems; Environmental Engineering and Management.
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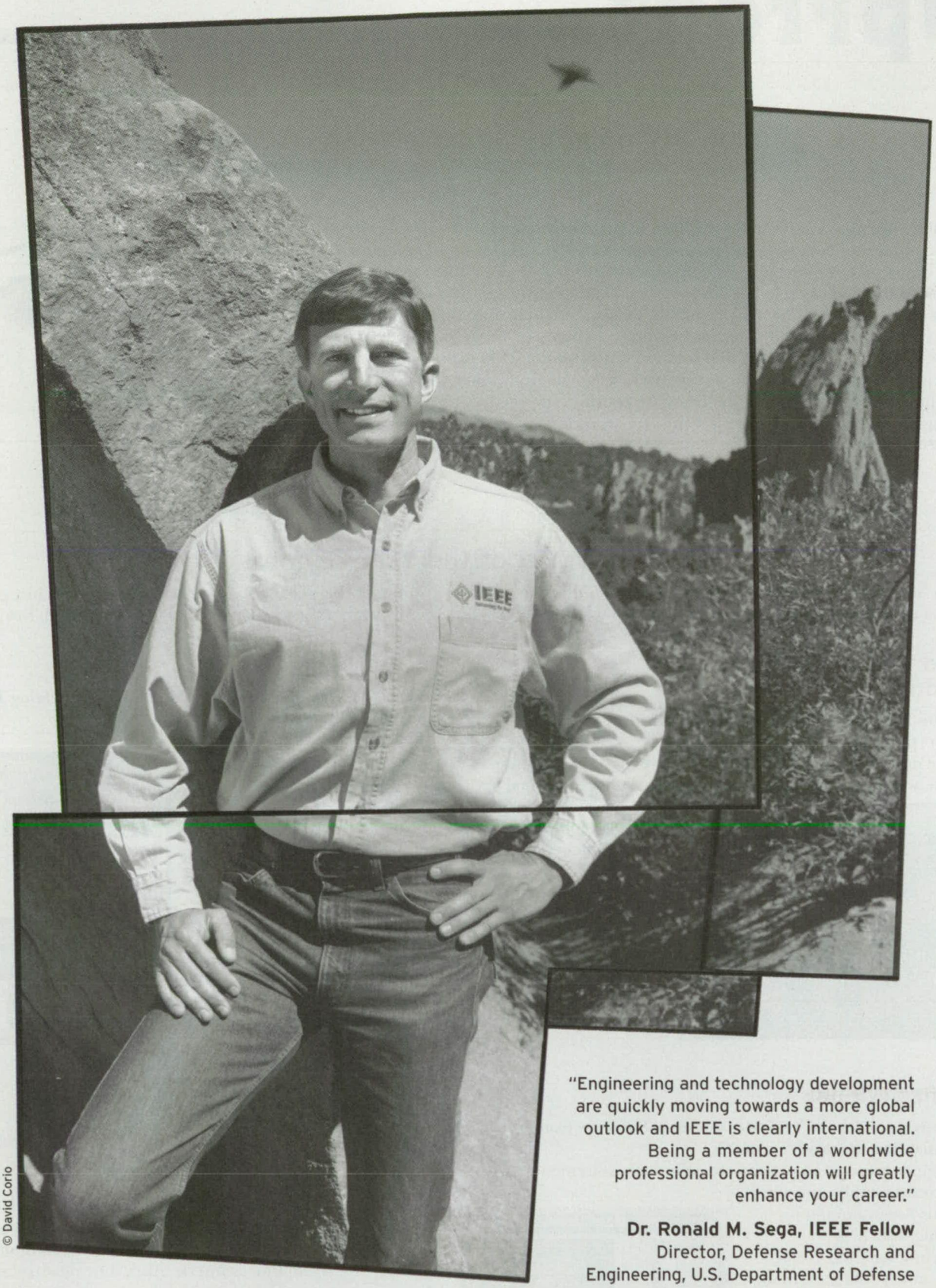

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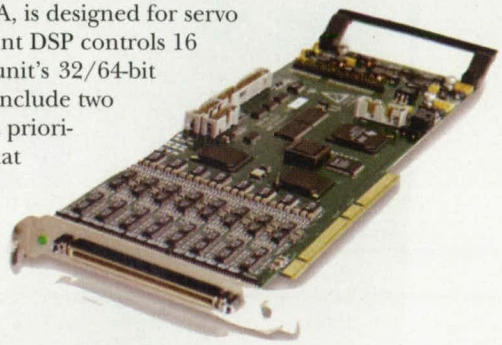
UpFront

PRODUCT OF THE MONTH

The Toro analog I/O DSP card from Innovative Integration, Simi Valley, CA, is designed for servo control and data acquisition applications. Its 150-MHz, 32-bit, floating-point DSP controls 16 simultaneous channels of independent A/D and D/A conversion. The unit's 32/64-bit PCI bus is capable of up to 264 Mbytes/second data bursts. On-chip resources include two 32-bit counter/timers, 16 DMA channels, 64 kbytes of dual-access SRAM, and a prioritized interrupt controller. The Toro features a choice of triggering modes that allows the user to select start/stop trigger events from on-chip timers, external trigger, and analog threshold on synclink signals from other cards. A built-in real-time event log in the firmware provides the user with a record of trigger times and user-defined events.



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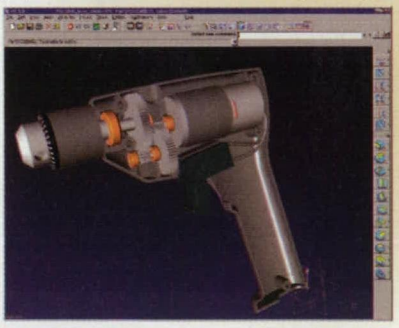
2001 Product of the Year Winners

On March 18, the winners of *NASA Tech Briefs*' Readers' Choice Product of the Year Awards were announced in Chicago at a special reception held during National Manufacturing Week. Here are the winners, as chosen by the readers of *NASA Tech Briefs*:

Gold Winner & Product of the Year

Version 5 VX CAD/CAM Software from **VX Corporation** (Palm Bay, FL)

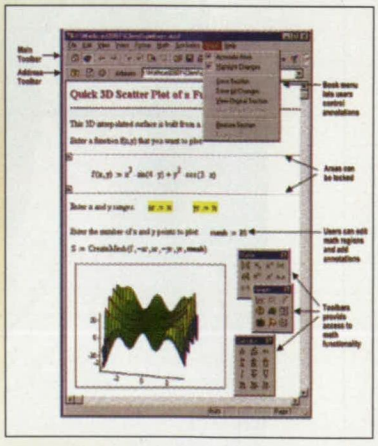
The design-through-manufacturing software eliminates the gap between CAD and CAM packages, and features manual and automatic healing of imported solid models, and direct import/translation of Pro/E, Catia, and Parasolid files. (www.vx.com)



Silver Winner

Mathcad® Client Software from **MathSoft Engineering & Education** (Cambridge, MA)

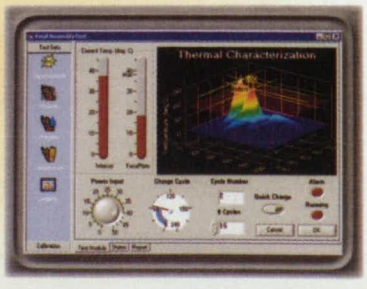
The software allows sharing and collaborating on Mathcad-created content across the Internet, and via corporate extranets and intranets. Users can interact with technical documents and applications, including Mathcad worksheets, electronic books, and MathML documents. (www.mathsoft.com)



Bronze Winner

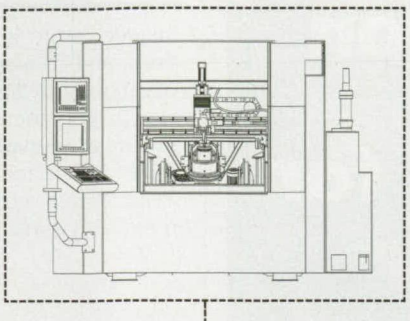
Measurement Studio™ 6.0 Measurement Software from **National Instruments** (Austin, TX)

Engineers use these tools to create test, measurement, and control applications in various programming languages such as LabWindows/CVI, Visual Basic, and Visual C++. Data is displayed in real-time 2D and 3D graphs and charts. (www.ni.com)



Next Month in NTB

The May issue will include highlights of the Product of the Year Awards reception, including photos and comments from our winners. Also, our feature on engineering on the Internet will include insights from leading vendors on which Web-based tools manufacturers are really using, and why e-engineering is still not a clearly defined market.



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Reader Forum is dedicated to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a technical problem, or an answer to a previously published question, post your letter to Reader Forum on-line at **www.nasatech.com,** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and e-mail address or phone number.

I'm looking for a device that can read the position of a laser beam on a screen or panel where the laser beam is pointing. The matrix has to be about 12" × 12" with a resolution of at least 0.1" or better. Thanks for any information.

George May
host@hsweb.net

Does anyone know who manufactures the silica tiles used on the Space Shuttle? Thanks.

Oddvar Dahle
oddvard@online.no

*(**Editor's Note:** Oddvar, there are actually three types of tiles that have been used on the Space Shuttle orbiters — the chief manufacturer of many of these is Lockheed Missiles & Space Division in Sunnyvale, CA. In addition, there is insulation blanket material, a quilted composite fabric, that has replaced most of the original low-temperature reusable surface insulation (LRSI) tiles. You can get complete information on all of the Thermal Protection System (TPS) components of the shuttle orbiters — including the protective tiles — by visiting the Shuttle Reference Manual Web site at: www.spaceflight.nasa.gov/shuttle/reference/shutref/orbiter/tps.)*

We are developing a device that will be used to detect high pressure and low pressure in the range of 10 to 40 mmHg. We are using a plastic tube 2.5 mm thick filled with water — infrared optosensors detect the upper and lower limits. It is working fine, except for the water drops that moisten the internal surface of the tube, and for the meniscus that comes presumably from surface tension and adhesive forces. These give us false readings. Any ideas on how to fix this problem would be appreciated.

Julian L. Ortuondo
julianor@att.net

I need to find a drive belt, compound-based o-ring as a redundant safety strap in case of mechanical fastener failure. Can anyone direct me to a resource for such information or statistics? Thank you.

Ken McMahon
ken@pivotgroup.com

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Sharon K. Miller, Senior Research Engineer, Glenn Research Center

Sharon K. Miller is the senior research engineer in the Electrophysics Branch of the Power and Onboard Propulsion Division at NASA's Glenn Research Center, Cleveland, OH. She has used atomic oxygen to restore damaged artwork and is currently working on a project that extends the life of the solar array blanket on the space station.

***NASA Tech Briefs*: How did you first get involved with the use of atomic oxygen to restore art?**

Sharon K. Miller: We were actually approached by the Cleveland Museum of Art through our commercial technology office. They were looking for ways to remove some varnishes that couldn't be removed by conventional solvents. Because of some space work that we had done using atomic oxygen to test the durability of some materials, we found that there was a reaction between atomic oxygen and carbon, which is contained in some of the varnishes and solvents they were using. Fire damage to art was also a large problem and we found it could be removed using atomic oxygen.

NTB: What is atomic oxygen and how is it applied?

Miller: Atomic oxygen is made in space by the ultraviolet radiation from the Sun breaking up the oxygen atoms that are in the atmosphere and which are very chemical reactant. We wanted to combine them with something so that they would react with the surfaces that contained carbon and convert them to carbon monoxide and carbon dioxide, which is left as a gas. We can generate atomic oxygen here on Earth in vacuum chambers using electric discharge, and we also have a technique by which we can create atomic oxygen in the air; it uses helium as a surrounding gas to prevent it from recombining.

NTB: Are there any other uses for the application of atomic oxygen?

Miller: There are a lot of things that it could be used for. It's good for sterilization. It could remove mold, and also the nutrients that molds need to grow, so it can affect the sterilized surface we use for medical implants. We are also looking at it as a way to provide a fine texture on surfaces for light scattering. For plastic surgery, you can make a surface that is rough for cells to attach to so you can foster cell growth. Cleveland Clinic is doing some studies to see whether it's a good surface for growing bone cells.

NTB: Can you explain more about the solar array blanket project?

Miller: A solar array blanket is the surface that the solar cells are bound to; it's sort of the structural member. It's a blanket because it's flexible. The solar array is huge — it's like a football field in length — and to get it up in the space shuttle, it has to be folded up. The solar array blanket is actually just a big sheet of polyamide, which is a plastic. The cells are mounted onto the surface of the plastic, and the whole sheet is folded up like a blanket and taken up and hurled while in orbit. It makes for a flexible surface and has the right kind of structural properties for what they want, but atomic oxygen does react with the polymer so you would lose the structural stability in less than a year if it weren't protected. We received a Space Act Award for finding a protective coating that would allow that surface to stay durable for the 15 years that it's supposed to last for the International Space Station.

A full transcript of this interview appears on-line at ***www.nasatech.com/whoswho****. Ms. Miller can be reached at sharon.k.miller@grc.nasa.gov.*

Six-axis Force/Torque Sensors

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Shown are ATI six-axis transducers from 17mm dia. to 330 mm dia.

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Prof. Francisco Valero-Cuevas
Neuromuscular Biomechanics Laboratory
Sibley School of Mechanical and Aerospace Engineering
Cornell University

"Because of their off-the-shelf solutions for miniature force and torque sensing, we were able to go from concept to working prototype in months instead of years."

Patrick Jensen, Ph.D., Assistant Professor of Ophthalmology
Johns Hopkins University

"The force/torque systems from ATI are ideal in our study of human grip force coordination and production. They are as close to a turn-key system that we have found."

Professor Jay L. Alberts, Ph.D.
Dept. of Health and Performance Sciences
Georgia Institute of Technology

ATI manufactures a variety of extremely robust six-axis Force/Torque (F/T) sensors that provide low-noise, high-resolution signals with output speeds of up to 10kHz and factors of safety up to 27 times measurement range. Since 1983, ATI has provided thousands of customers with F/T's ranging from the smallest six-axis sensor in the world (17 mm diameter) to sensors measuring thousands of pounds. The F/T can provide data via voltage outputs, RS-232 serial or interface with either ISA, PCI, PCMCIA or cPCI buses. ATI is developing interfaces to Firewire, VXI, USB, DeviceNet and Ethernet. The F/T can also interface with analog data acquisition systems (seven channels required).

For more information, contact Milton Gore at mgore@ati-ia.com or extension 132.

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Books & Reports

The Complexity of the Diagnosis Problem

A report presents a study of the complexity of an algorithm that performs model-based diagnosis of a complex hardware system. [In model-based diagnosis, an algorithm detects logical inconsistencies between observational data and a description (mathematical model) of the system.] In the study, the problem of detecting logical inconsistencies is transformed into the problem of finding prime implicants of a monotone Boolean function. This transformation enables utilization of the well-developed machinery of Boolean function theory, not directly accessible in the logical approach: one can work with monotone Boolean functions described by polynomial-size monotone circuits instead of attempting to deal with logical objects and performing exhaustive searches in order to extract all desired information. One especially notable result achieved in this study through the Boolean-function approach is the first analytical proof that the diagnosis problem is *NP*-complete. The report asserts that the discovery of the connection between diagnosis and the Boolean functions may afford new means to solve the diagnosis problem — in particular, to develop diagnostic algorithms that take super-polynomial amounts of time, in contrast to the exponential amounts of time heretofore needed to solve *NP*-complete problems.

This work was done by Farrokh Vatan of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "The Complexity of the Diagnosis Problem," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*
NPO-30315

Design Concepts for the ISS TransHab Module

Twelve reports present concepts for the design of structural and functional systems, subsystems, and components of the proposed TransHab module — an inflatable, lightweight habitation module that would be used by crewmembers of the International Space Station and would serve as a prototype of habitation modules for future spacecraft on long missions (e.g., missions to Mars). The TransHab module would be a unique hybrid structure that would combine the packaging and mass efficiencies of an inflatable structure with the advantages of a load-bearing hard structure. The governing design concept is one of a high degree of integration and multifunctionality of all parts of the TransHab system. The reports include sketches (some containing estimated dimensions) and discussions of engineering requirements. There are also numerous discussions of human factors (psychological, social, and physiological) that affect many aspects of design. Although the reports address issues specific to the TransHab module, some of the concepts discussed may be applicable to the design of temporary or transportable housing for use on Earth.

This work was done by Kriss J. Kennedy and Jasen L. Raboin of **Johnson Space Center** *and Constance M. Adams, Kurt Bush, and Jose Christian of Lockheed Martin. To obtain copies of the reports, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Machinery/Automation category.*
MSC-23090/91/181-187/189-191

Characteristics of Supercritical Transitional Mixing Layers

This report describes a study of three-dimensional, temporal mixing layers between different fluids initially flowing at different velocities under supercritical conditions. The study involved direct numerical simulations by use of a validated mathematical model of high-pressure-fluid behavior that has been described in a number of prior *NASA Tech Briefs* articles. In some cases, the fluids were heptane and nitrogen; in other cases, they were hydrogen and oxygen. In all these simulations, the mixing layers underwent transition to turbulence.

This work was done by Josette Bellan and Nora Okong'o of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Characteristics of Supercritical Transitional Temporal Mixing Layers," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
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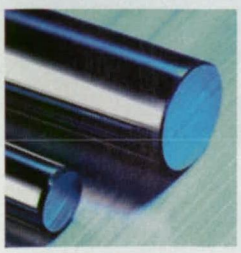

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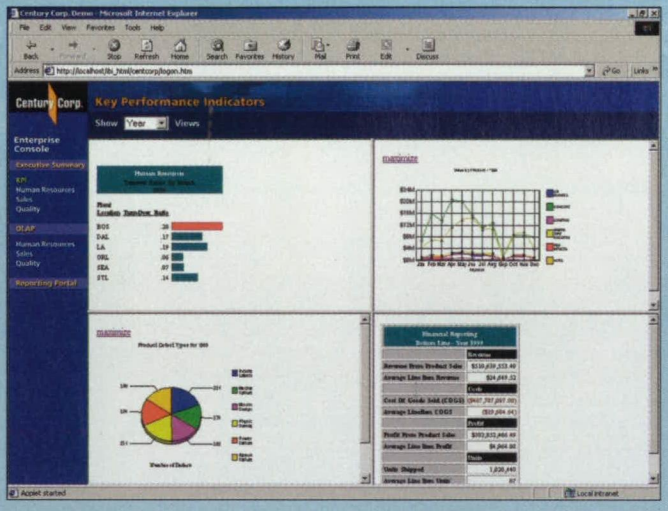
The Shuttle Processing Directorate (PH) at NASA's Kennedy Space Center is responsible for preparing the shuttle for a safe and successful mission. Before each flight, all of the systems and components must be checked, tested, adjusted, and, if necessary, repaired or replaced. To help manage the refurbishment process, PH integrated technology from Information Builders to develop the Insight System, a Web-driven reporting system that monitors contractor performance and reports on the status of the launch preparation effort.



Created as a final checkpoint to gauge mission readiness, "The Insight System reduces NASA's daily involvement in missions and increases the time engineers spend on analysis — a capability we did not possess before," according to Ron Phelps, project manager at Kennedy.

Insight had to complement NASA's existing mainframe-based Shuttle Processing Data Management System (SPDMS), accessing data in several different database formats, and tying together various NASA and contractor databases on different platforms. The WebFOCUS data publishing and reporting system provides users with reports via any standard Web browser, so Phelps used the system to construct an environment that allowed NASA to embed a link between its Web pages and data in the SPDMS.

The Insight System is being constructed in three phases. During Phase I, NASA developed a prototype to familiarize users with the basic capabilities and define data warehouse architecture. Phase II refined what was learned in the first phase by creating more reports and training users. Currently, Insight is entering Phase III, an ongoing process of creating final, production-ready reports and ensuring the warehouse contains all necessary data.

"At the end of Phase III, we'll have a production system in place serving several hundred users," said Phelps. "When it comes to the final countdown of a shuttle mission, Insight gives us confidence that we're ready for launch."

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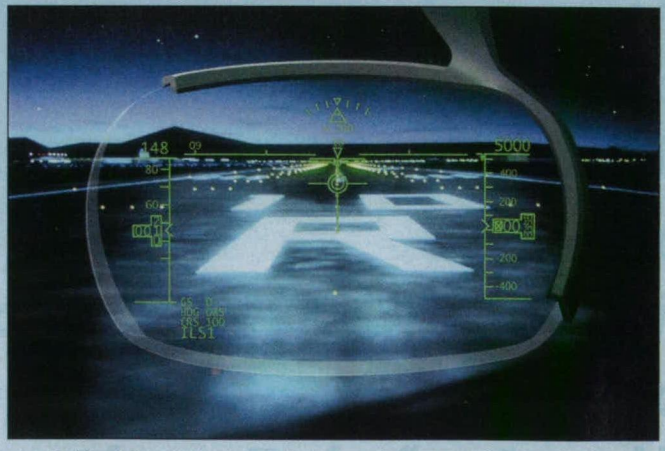
Global Positioning System Helps Pilots Fly Safer

Synthetic Vision Information System (SVIS)
Rockwell Collins
Cedar Rapids, IA
319-295-1000
www.rockwellcollins.com

In a partnership with NASA's Aviation Safety Program, Rockwell Collins has developed the Synthetic Vision Information System (SVIS), a visually based system designed to increase safety and terrain awareness during approach and departure operations. With SVIS, the typical view from the cockpit is augmented with a computer-generated display to give pilots artificial visibility in poor weather conditions. The synthetic views can be displayed head-up or head-down. "With global positioning system signals, pilots now know exactly where they are," said Michael Lewis, director of NASA's Aviation Safety Program. "Add super-accurate terrain databases and graphical displays, and we can draw three-dimensional moving scenes that will show pilots exactly what's outside."

Tunnel guidance is part of the display that creates a visual cue for pilots to relate to the intended flight path. This is then



overlaid with synthetic terrain images, which are generic and producible in current-generation avionics architectures. With the tunnel guidance system, pilots can fly complex procedures without creating additional pilot workload.

Pilots from the US Federal Aviation Administration (FAA), Boeing, Delta Air Lines, United Air Lines, and American Airlines participated in flight tests of the system. The pilots found the system to be controllable, comfortable, and easy to fly.

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Technologies of the Month

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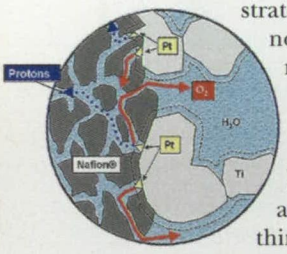
Minimizing Catalyst While Maximizing Electrode Performance

Pragmatic Vision International LLC

Platinum and other platinum group elements are used as catalysts in electrodes. Unfortunately, the high cost of platinum creates a large obstacle in the production of technologies such as proton-exchange-membrane (PEM) and direct methanol fuel cells, where the platinum is as much as 20% of the system cost. A fabrication process for catalytic electrodes can precisely place and form the catalyst on the electrode substrate, reducing the amount of expensive catalyst needed.

PVI's electrodes consist of conducting carbon fiber substrate and particles of catalyst. The technology is similar to electroplating, but rather than plating the entire substrate, the catalyst is targeted only to sites that have access to the channels in the gas diffusion layer. The catalyst can be deposited in any amount or concentration, in layers as thin as a single atom. As a result, there is virtually no wasted material.



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Low-Cost, High-Volume Ether Compound Production

Kao

Cosmetics, lubricants, solvents, emulsifiers, and detergents contain ether compounds, which are not easy to manufacture on a cost-to-volume basis. Kao has developed a manufacturing method that yields an ether compound at a high production rate in a single step. Central to the process is a reaction using a hydroxy compound with a carbonyl compound, or carbonyl compounds by themselves. The materials are reacted under a hydrogen gas atmosphere in the presence of a catalyst such as palladium or a palladium compound. Iridium, osmium, and rhenium can also be used, supported on a carrier such as carbon, silica-alumina, zeolite, alumina, or silica.

The process does not require solvents, but the reaction can be diluted with a solvent. This single-step manufacturing process enables ether compounds having large molecular weight or asymmetric structures to be produced in large volumes at low cost, making it suitable for use in high-volume applications.

Get the complete technology on this technology at:
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Thickening Agent Improves Paint Stability, Processing, and Clean-up

The Procter & Gamble Company

Non-aqueous suspensions such as inks, paints, and coatings have been thickened with clays, silica, and polymers. These thickeners, called *structurants,* rely upon interactions with formula components, which results in non-aqueous structures that can separate easily, be unstable, and be highly sensitive to any formula variation. A thickening agent called CLASS (Crystalline LAS Structurant) builds structure by interacting with itself, forming stable, non-aqueous compositions that are insensitive to pH and electrolytes.

The structuring particle is delivered as dry flake or predispersed gel in a compatible solvent. Because it is water-soluble, the structure breaks down upon contact with water or surface moisture, which could enable faster, easier clean-up in applications with paint or ink.

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Supercharger Improves Engine Performance

Bill Berlinger, Caterpillar

One method of improving engine performance compresses inlet air in the combustion chamber, "supercharging" the combustion process and increasing power output without increasing engine size. A new technology called the COMPREX Pressure Wave Supercharger provides compressed intake air without the delay of a turbocharger or the blower of a conventional supercharger.

COMPREX consists of a simple rotor with axially arranged cells, separate gas and air casings, a mantle, and bearing unit. Exhaust gas flows through the gas casing into the rotor. The quick opening of the rotor cells toward the high-energy exhaust gas creates a sonic pressure wave that compresses the fresh intake air allowing engine response to be improved even at lower engine speeds. The vehicle can now be driven in higher gears and at lower engine speeds with excellent acceleration.

Get the complete technology on this technology at:
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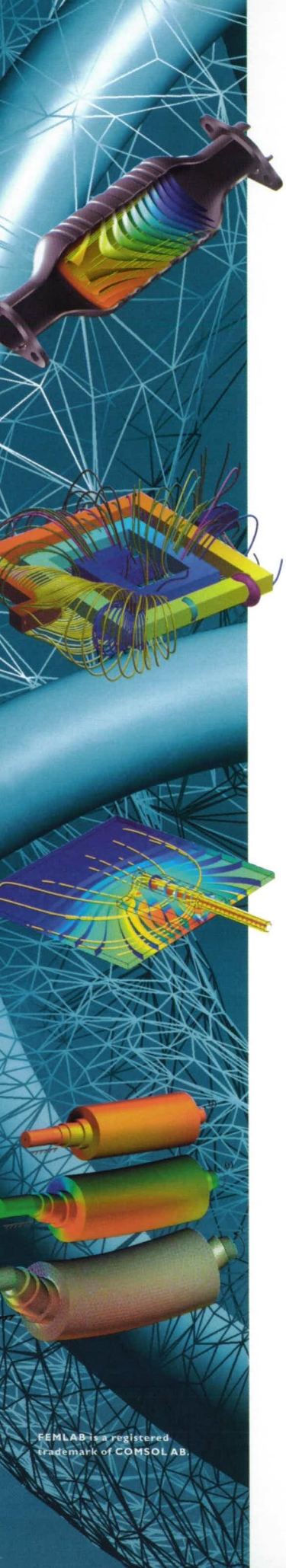

The most common reactor for environmental protection, which we encounter or use everyday, is the catalytic converter in automobiles. In these monolithic catalysts, carbon monoxide and nitrous oxides are converted into relatively harmless species like carbon dioxide and nitrogen. To optimize the utilization of the expensive catalyst, it is important to be able to model the reactor at different operational conditions. In this FEMLAB model, mass and heat balances are coupled to compute temperature distribution and flowlines in the reactor.

This square-shaped spiral inductor is used for bandpass filters in micro electromechanical systems (MEMS). The FEMLAB simulation takes the nonuniform current density in the coils into account to compute an accurate magnetic flux arround the coils. The inductance of this inductor is 2.1 nH, which is obtained by integrating the magnetic energy. Using the programming language of FEMLAB for parametric analysis, you can find the correlation between the induction and the input parameters of the model.

In the design of electrodes for water electrolysis, it is important to minimize the voltage losses at a given total current. FEMLAB modeling helps the engineer in the design of the electrode geometry and the current collector. The model gives the current density distribution and the potential distribution in the system. These results make it possible to avoid excessive degradation of the active electrode surface and overheating of the welds at the position of the current collector.

When designing an electric motor it is important to design the rotor shaft so that no eigenfrequencies exist in the working range of the rotational speed. It is also important to study the shape of the eigenmode and not just the eigenfrequencies. In the eigenfrequency analysis, one end of the shaft is fixed and the other end is free to rotate and axially deform. The image shows deformation and rotation angle in the second eigenmode, using different visualization options like colormaps and scaling.

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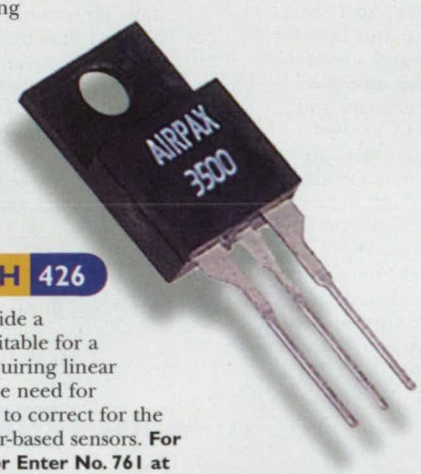
A Sneak Preview of Sensors Expo

The Spring 2002 Sensors Expo brings together a wide range of innovations shaping the sensing, MEMS, data acquisition, control, and communications industries. Held at the San Jose Convention Center from May 21-23, Sensors Expo will feature the latest advances in biosensors and bio-MEMS, intelligent systems and smart sensors, and nanotechnology, and will give visitors the chance to speak one-on-one with innovators.

Look for the following new products that will be on display. For more information on the show, visit www.sensorsexpo.com.

Airpax Thermal Sensing Products, Frederick, MD, will exhibit the VeriSense™ 3500 thermal sensors that offer typical accuracies of ±1/4°C at room temperatures and ±3/4°C over the 0°C to 100°C temperature range. Housed in a TO-220 package, the sensors provide a voltage output and are suitable for a variety of applications requiring linear output. They eliminate the need for compensating electronics to correct for the non-linearity of thermistor-based sensors. **For Free Info Circle No. 761 or Enter No. 761 at www.nasatech.com/rs**

BOOTH 426



The RT12-4204™ seamless wireless sensor transceiver from Advanced Embedded Systems, Tucson, AZ, is a controller that converts a wired system into a wireless connection. It allows connection between any 4-20 mA, 0-5 VDC or 0-10 VDC sensor and a data logger, controller, or SCADA equipment, eliminating up to 20 miles of wiring. The transceiver accepts up to four analog inputs and two optically isolated inputs/open collector outputs. It also has the ability to act as a signal converter by allowing independent configuration between the INPUT and OUTPUT modules. **For Free Info Circle No. 760 or Enter No. 760 at www.nasatech.com/rs**

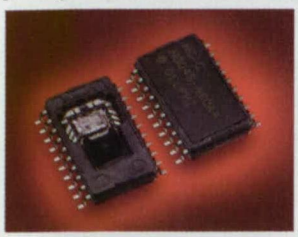
BOOTH 713

The MT2A miniature position transducer from Celesco Transducer Products, Chatsworth, CA, features a tensioned measuring cable designed for acceleration encountered in flight testing and automotive crash tests. Available in measuring ranges of 0-9", 0-15", and 0-30", the transducer is designed with 2-axis 360° rotation in its mounting bracket. Also displayed in the booth will be the Jumo Midas pressure transmitters from JUMO Process Control, Coatesville, PA. The transmitters use a ceramic thick-film transducer that converts the pressure into a standardized voltage or current signal. They can be used in liquid and gaseous media. **For Free Info Circle No. 763 or Enter No. 763 at www.nasatech.com/rs**

BOOTH 318

The INTELLEK® low-g accelerometer from Delphi Automotive Systems, Troy, MI, measures linear changes in acceleration with programmable scale factors from .75 g to 3 g. The micro-sized module combines a sensor and an integrated circuit in a 20-pin package. Features include a self-test diagnostic that simulates actual acceleration when power is first applied, and operation from a single 5-volt power supply. **For Free Info Circle No. 765 or Enter No. 765 at www.nasatech.com/rs**

BOOTH 513



Oceana Sensor, Virginia Beach, VA, introduces the TX3APN, tri-axial accelerometer, a transistor-packaged, hermetically sealed device that utilizes ceramic, shear structured sensing elements to measure vibration in three orthogonal directions. It features low input power requirements, and a 100-mV/g sensitivity of a frequency range of 1-10K on the z-axis, and 1-4K on the x and y-axis. Applications include machinery health monitoring, impact detection, structural acoustics, and pipe leak detection. **For Free Info Circle No. 775 or Enter No. 775 at www.nasatech.com/rs**

BOOTH 411

Version 6.0 electromagnetic design and simulation software is available from Integrated Engineering Software, Winnipeg, Canada. Enhancements to the software's geometric modeler, CAD interoperability, and design optimization include a 2D mode that allows users to switch from 2D mode to 3D mode. Surfaces on the upgrade exist as NURBS and the segments define the boundary of the surface. Users also have the ability to generate high-resolution 3D shaded geometry. The new version enables connection directly to five leading CAD programs, enabling users to import models from SolidWorks, SDRC, Solid Edge, Pro/ENGINEER, and Autodesk products. **For Free Info Circle No. 767 or Enter No. 767 at www.nasatech.com/rs**

BOOTH 325

Kistler Instrument Corp., Amherst, NY, offers the ServoK-BEAM accelerometer, an analog force feedback sensor that utilizes a silicon micromachined variable capacitance sensing element. The sensor features 1,500 mV/g sensitivity and a resolution of 1 µg. It is a calibrated unit that combines the sensing element and integrated electronics in a sealed aluminum housing. Four through-holes enable the unit to be mounted to the test structure with screws. The accelerometer operates from a single power supply between ±6 and ±15 VDC with 8 mA typical current consumption. **For Free Info Circle No. 769 or Enter No. 769 at www.nasatech.com/rs**

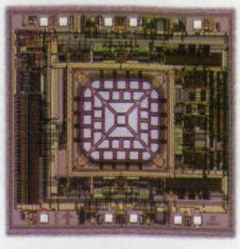
BOOTH 519

MicroStrain, Burlington, VT, will display the FAS-G inertial tracking device that leverages two solid-state MEMS accelerometers, an angular rate sensor, and embedded software tracking algorithms for performance over a 360° measuring range. Applications include robotics positioning, biomechanics joint angle tracking, dynamic and static tilt sensing, vehicle roll detection, compass tilt compensation, and heavy equipment stabilization. The device relies on a gyro to track fast angular movements, and on the DC response of the accelerometers to track static angular position. **For Free Info Circle No. 773 or Enter No. 773 at www.nasatech.com/rs**

BOOTH 406

The MXA2500U and MXD2020UW low-noise, dual-axis accelerometers from MEMSIC, Andover, MA, are fabricated on a standard, submicron CMOS process that measures acceleration with a full-scale range of ±1 g and a sensitivity of 500 mV/g. The MXA2500U provides an absolute analog output and the MXD2020UW provides a ratio of pulse width to position digital output. Both measure dynamic acceleration and static acceleration, are hermetically sealed, and are operational over a -40°C to 105°C temperature range. **For Free Info Circle No. 772 or Enter No. 772 at www.nasatech.com/rs**

BOOTH 821



Fluorescence-based optical sensors from Ocean Optics, Dunedin, FL, include optrodes for analyzing pH in aqueous solutions and for use in *in vivo* procedures. The pH sensors operate using a fluorescein derivative, with pH measurement directly related to the magnitude of the fluorescein's fluorescing peaks. The optical sensor series includes chemical sensors that utilize sol-gel thin-film coatings. They connect to miniature fiber-optic spectrometers and a 470-nm Blue LED light source for real-time sample analysis. **For Free Info Circle No. 776 or Enter No. 776 at www.nasatech.com/rs**

BOOTH 1020

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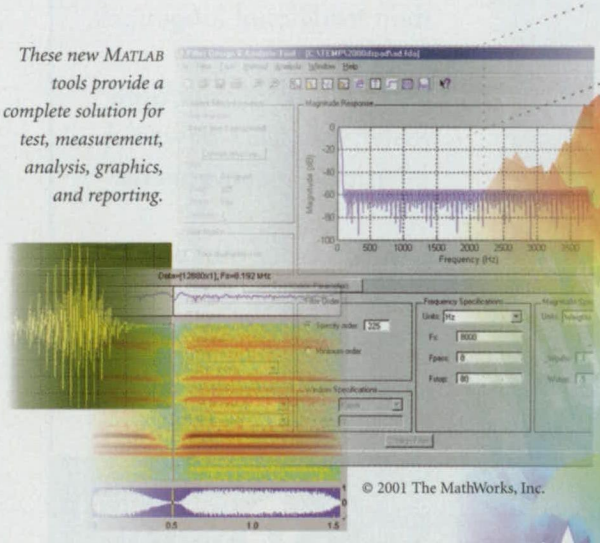

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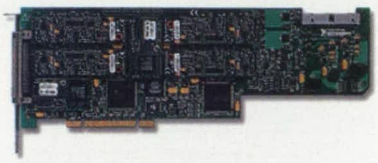
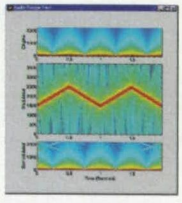
National Instruments, Austin, TX, will exhibit the 12-bit NI PCI-6115 simultaneous-sampling, multifunction I/O device that delivers digital, analog, and mixed-signal capabilities for high-frequency data acquisition applications. It features simulataneous analog input and output, two on-board memory options, and samples at a maximum of 10 MS/s on each of four input channels. The device also features two 12-bit output channels capable of 4 MS/s, eight digital I/O lines, two 24-bit counter/timers, and a RTSI™ bus for board synchronization. The unit comes with NI-DAQ™ 6.9 driver software for use with numerous programming languages. **For Free Info Circle No. 774 or Enter No. 774 at www.nasatech.com/rs**



BOOTH 801

The MathWorks, Natick, MA, will feature its MATLAB® 6 environment for applications in engineering and science that includes tools for mathematical computation, analysis, visualization, and algorithm development. The Data Acquisition Toolbox 2.1 enables control and communication with a variety of PC-compatible data acquisition hardware. With the toolbox, users can configure external hardware devices, read data into MATLAB for analysis, or send data out. Also exhibited will be the Instrument Control Toolbox 1.1 that lets MATLAB communicate with instruments such as oscilloscopes and function generators. Data can be generated in MATLAB to send to an instrument, or can be read into MATLAB for analysis and visualization. **For Free Info Circle No. 771 or Enter No. 771 at www.nasatech.com/rs**

BOOTH 728

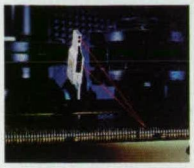


Druck, New Fairfield, CT, will display the PTX 7200 Series pressure transmitters that use piezoresistive silicon technology packaged in a welded stainless steel housing. The 316L SS housing and Hastelloy C276 diaphragm are NACE MR-01-75 compatible. All ranges from 1 to 10,000 PSI are available in gauge or absolute pressure with a 2-wire, 4-20 mA output. Operating temperature range is -40°F to 210°F. **For Free Info Circle No. 766 or Enter No. 766 at www.nasatech.com/rs**

BOOTH 809

Differential pressure transducers from Kavlico, Moorpark, CA, can be specified with pressure ranges of 1" of water to 0-50 PSID, and operate on a 5 VDC power supply, providing a 0.5 to 4.5 VDC output. The transducers are suitable for ventilation, water flow, gas flow, air intake flow, exhaust gas flow, coolant flow, oil flow, fuel flow, product mixing, and blending applications. The transducers have no moving parts, and provide flow measurement options when coupled with venturi tubes, flow nozzles, orifice plates, or pitot tubes. **For Free Info Circle No. 768 or Enter No. 768 at www.nasatech.com/rs**

BOOTH 719



BOOTH 1013

The F3C-AL laser sensor from OMRON Electronics, Schaumburg, IL, can detect a 1-mm target from a distance of 700 mm. Its black/white error eliminates the need to reset parameters or change sensors when changing colors, materials, or inclination. The sensor features background suppression, and contains a red laser light spot that facilitates alignment with the target. It is suitable for semiconductor, assembly automation, material handling, automotive, electronics, machine tool, and packaging applications, and incorporates an auto power control function. **For Free Info Circle No. 777 or Enter No. 777 at www.nasatech.com/rs**

Crossbow Technology, San Jose, CA, will display its MICA sensors and tools that enable development of wireless sensor networks for monitoring and detecting a variety of targets. The MICA architecture consists of MPR and MTS sensors and wireless communication processor modules. The sensors can detect ultra-small vibrations, acoustic noise, magnetic disturbances, conventional light, temperature, and proximity. A sensor interface port enables incorporation of chemical and biological sensor technology. **For Free Info Circle No. 764 or Enter No. 764 at www.nasatech.com/rs**

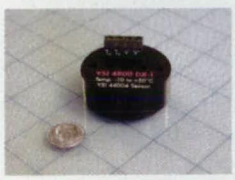
BOOTH 512

RDP Electrosense, Pottstown, PA, offers the MCL range tension and compression amplified load cells that couple a capacitive sensor the miniaturized conditioning electronics in a compact housing. The internal electronics provide a level ±10 VDC output. The units come in two compact models, with the smaller measuring 1.22 x 1.75". Also featured will be the DCTH series displacement transducers for interface with control systems and AD converters. **For Free Info Circle No. 778 or Enter No. 778 at www.nasatech.com/rs**

BOOTH 1008

YSI Temperature, Yellow Springs, OH, offers the 4-20 mA loop-powered 4800 DX-1 thermistor transmitter for process monitoring applications. The transmitter has an accuracy of ±0.1°C and is available in two temperature ranges: -10°C to 50°C for biomedical applications; and 0°C to 100°C, which is compatible with YSI configure-to-order probes. **For Free Info Circle No. 781 or Enter No. 781 at www.nasatech.com/rs**

BOOTH 524



The DCS™ Smarteye® RS-232 compatible, digitally controlled, photoelectric sensors from Tri-Tronics, Tampa, FL, can be set up, monitored, and controlled directly from a computer screen. The sensors are compatible with computers, PLCs, embedded controllers, or any control device equipped with an RS-232 serial port. They provide an on-screen oscilloscope style contrast deviation analyzer that allows the operator to tweak the adjustment for the most reliable setting. Benefits of computer screen control include set-up by use of icons, graphical performance monitor, configurable performance options, performance memory settings, and timer options. **For Free Info Circle No. 779 or Enter No. 779 at www.nasatech.com/rs**

BOOTH 313

Yokagawa Corporation of America, Newnan, GA, offers the MV100 and MV200 MobileCorders that provide data logging capability over a range of measurement applications. The MV100 is available with up to 12 universal inputs and features a 5.5" color TFT LCD display. The MV200 is available with up to 30 universal inputs and features a 10.4" color TFT LCD display. Both models offer a choice of removable storage media, standard 1.44-MB floppy disk, or an optional 100-MB Zip or 160-MB PCMCIA ATA flash memory card. The units can be used as portable test instruments, or on a bench-top. **For Free Info Circle No. 780 or Enter No. 780 at www.nasatech.com/rs**

BOOTH 1120

For Free Info Circle No. 518 or Enter No. 518 at www.nasatech.com/rs

Electrometer for Triboelectric Evaluation of Materials

Some materials should be distinguishable by their triboelectric responses.

NASA's Jet Propulsion Laboratory, Pasadena, California

An electrometer developed for measuring the triboelectric responses of soils on Mars is also potentially useful on Earth for identifying some materials via their triboelectric responses. In operation, an array of triboelectric sensors is rubbed against the material of interest for a predetermined distance, then withdrawn from the material of interest at a predetermined speed. During this operation, the electrometer circuitry measures the time-varying sensor output voltages, which are proportional to the electric charges induced on the sensors by the rubbing. The resulting voltage-vs.-time data constitute the desired triboelectric-response data. If materials that one seeks to identify or to distinguish from each other exhibit unique, known triboelectric responses that have been catalogued, then a sample of unknown material can be identified by seeking a match between its triboelectric response and one of the catalogued responses.

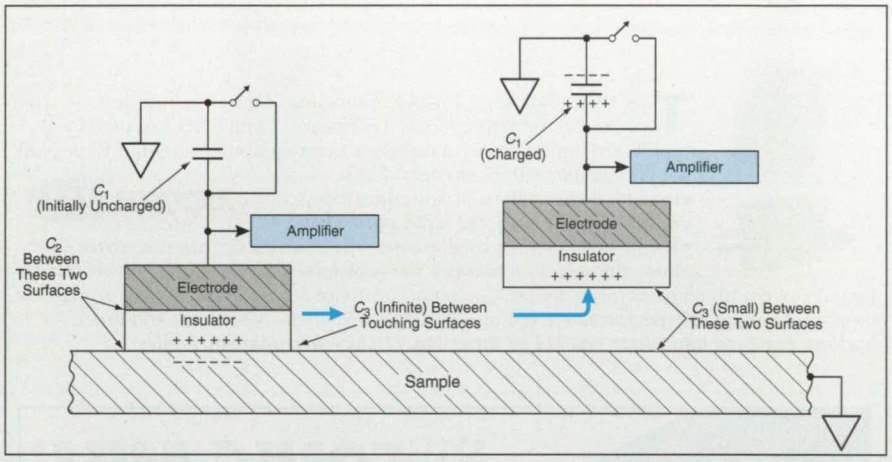


Figure 1. The **Insulator Is Rubbed** along the surface of the sample, then withdrawn. The rise and decay of the triboelectric charge induced by the rubbing is indicated by the time-varying output voltage of the amplifier.

Figure 1 is a simplified schematic depiction of one of the triboelectric sensors connected to a charge-sensing circuit (charge-to-voltage converter). This converter is a conventional electrometer circuit that includes a capacitor (C_1) and an operational amplifier in a follower configuration. The triboelectric sensor is an electrode covered with a layer of insulating material. The outer surface of the insulating material is what is rubbed against the material of interest.

The capacitance between the outer surface of the insulator and the electrode is C_2. The voltage associated with the triboelectric charge that accumulates on the rubbed insulator surface is coupled, via this capacitance, to the C_1/amplifier node. Initially during rubbing, the switch shown in Figure 1 is kept closed to prevent C_1 from charging, thereby constraining the electrometer input and output voltages to be zero. At a designated point during rubbing, the switch is opened, allowing C_1 to charge and the electrometer output voltage to depart from zero.

The triboelectric response — that is, the electrometer output voltage as a function of time — depends on several factors, including the following:

- The triboelectrically induced charge (Qi) present at the instant of liftoff following rubbing;
- C_1, C_2, and amplifier-circuit resistances;
- The speed of withdrawal;
- The time-varying capacitance C_3 between the rubbed insulator and sample surfaces; and
- The electrical resistivities of the insulator and sample materials.

Figure 2 shows triboelectric responses from an experiment in which five sensors made with five different insulating materials were rubbed against wool felt.

Electrometers based on this concept might be useful in industrial settings for inspecting and identifying incoming materials; for example, to identify fabrics coming into a clothing factory. Another potential use could be distinguishing between contaminated and uncontaminated soils. Another application might be evaluating moisture contents of soils; this should be possible because the rate of decay of triboelectric charge depends on humidity.

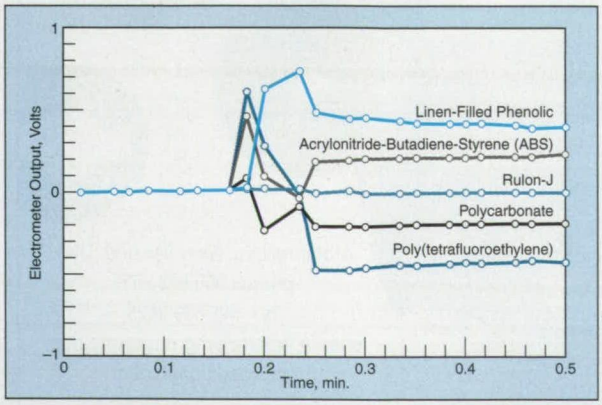


Figure 2. These **Five Triboelectric Responses** were obtained from rubbing five triboelectric sensors against wool felt. The insulators on the sensors were made from the noted materials.

This work was done by Martin Buehler and Raymond Gompf of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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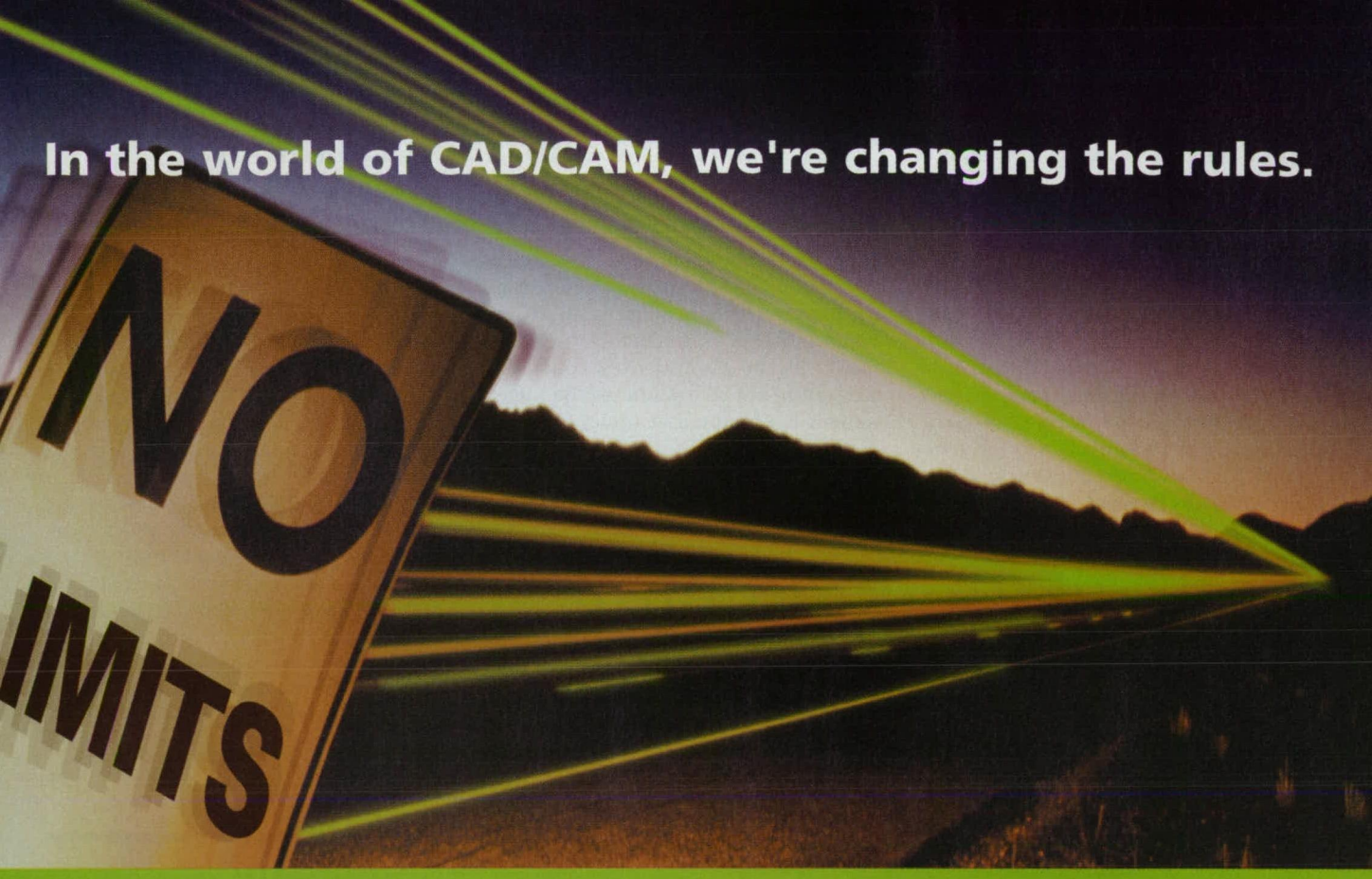
Refer to NPO-20684, volume and number of this NASA Tech Briefs *issue, and the page number.*



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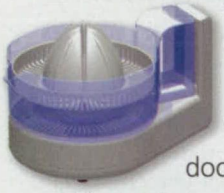

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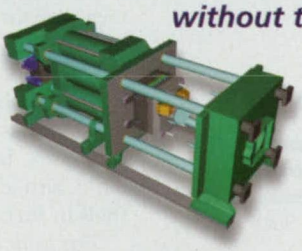

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Infrared CO_2 Sensor With Built-In Calibration Chambers

John F. Kennedy Space Center, Florida

A proposed infrared CO_2 sensor, operated in conjunction with suitable readout, data-processing, and control circuitry, could be calibrated repeatedly during operation to compensate for changes in sensor response induced by such phenomena as aging and changes in temperature. The sensor would include an infrared source, an infrared detector, and four chambers containing CO_2 at various concentrations. Three of the chambers would be calibration chambers: they would be sealed and would contain CO_2 at known low, intermediate, and high concentrations, respectively. The fourth chamber would be filled with the gas under test containing CO_2 at a concentration to be determined. There would be optics for multiplexing infrared radiation from the source through the four chambers and demultiplexing the radiation from the chambers to the infrared detector. During an operation/calibration cycle, radiation would be directed through each chamber in turn, and the response of the detector recorded for each chamber. A three-point calibration for that cycle would be computed from the responses for the three calibration chambers. Then the concentration of CO_2 in the fourth chamber would be computed by simply multiplying the detector response for that chamber by a factor calculated as part of the calibration.

This work was done by Jose M. Perotti and Gregory A. Hall of **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
KSC-12177

Solid-State Potentiometric CO Sensor

John F. Kennedy Space Center, Florida

A solid-state sensor was developed that measures the concentrations of one or more gases of interest in a mixture of gases. This simple solid-state sensor produces a voltage signal that is sensitive to CO concentration from percent to ppm (parts per million) levels. It was intended originally for use in measuring concentrations of carbon monoxide in fuel and oxidizer gases generated on Mars in a process that would include the decomposition of atmospheric CO_2 into CO and O_2. In that application, the sensor would be capable of measuring high concentrations of CO expected to occur on the fuel side of the process, yet would be selective and sensitive enough to measure the low concentrations of CO in O_2 expected on the oxidizer side of the process. On Earth, sensors like this one could be used to detect toxic concentrations of CO emitted in diverse processes, including refining of petroleum and combustion of hydrocarbon fuels in furnaces and automobiles.

This work was done by Eric D. Wachsman and Abdul-Majeed Azad of the University of Florida for **Kennedy Space Center**. *For further information contact the Kennedy Commercial Technology Office at 321-867-6224.*
KSC-12256

Planetary Rover Absolute Heading Detection Using a Sun Sensor

Headings are accurate to within a few degrees.

NASA's Jet Propulsion Laboratory, Pasadena, California

A relatively inexpensive Sun sensor for determining the absolute heading of planetary rovers to within ± 3° using a monochrome charge-coupled device (CCD) camera is presented. The Sun sensor was developed for the Field Integrated, Design and Operations (FIDO) rover. This rover is an advance technology rover that is a terrestrial prototype of the rovers that NASA/JPL plans to send to Mars in 2003. The goal of the FIDO team was to develop a Sun sensor that fills the current cost/performance gap, uses the power of sub-pixel interpolation, makes use of current hardware on the rover, and demands very little computational overhead. In addition, a great deal of emphasis was placed on robustness to calibration errors and the flexibility to make a transition to a flight rover with very little modification.

The resulting Sun sensor, which is shown in Figure 1, consists of a CCD monochrome camera, two neutral-density filters, a wide-angle lens, and housing. The neutral-density filters reduce incident light to capture only the Sun's disk. The Sun sensor camera is modeled as a fish-eye camera/lens system with 21 parameters; the parameters are computed in the calibration procedure that can be performed easily and even "on the fly." The Sun sensor captures images of the Sun using an onboard frame grabber mounted on the rover-computing stack. The centroid of the Sun in the image is the main feature needed for determination of the rover heading. Centroid extraction follows a three-step process: thresholding, artifact removal, and center of mass/circularity determination. From the Sun centroid a 3-D unit ray vector is computed from the sensor frame to the Sun using the camera model. The 3-D vector is then transformed into a gravity-down rover reference frame by use of the roll- and pitch-angle outputs of an inertial sensor that is part of the onboard rover navigation system. The azimuth and elevation of the Sun with respect to the rover reference frame are then determined. By use of solar ephemeris data and the equation of time from the Astronomical Almanac, the azimuth and elevation of the Sun are determined for the applicable longitude, latitude, and universal time (UT). The UT is obtained from the rover computer clock and corrected to the nearest second. Finally, the heading

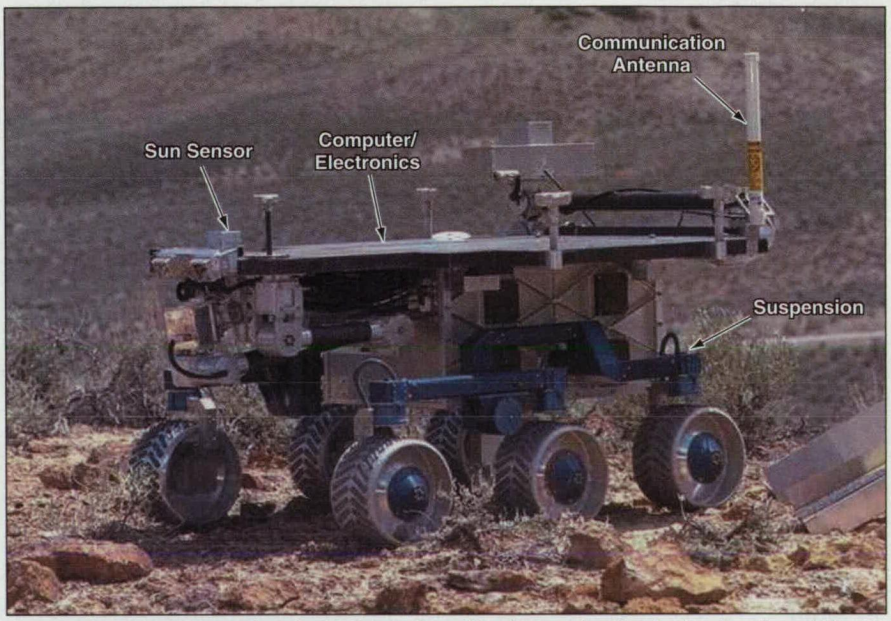

Figure 1. **Sun Sensor** mounted on the FIDO rover is used for determining the absolute heading within ±3°.

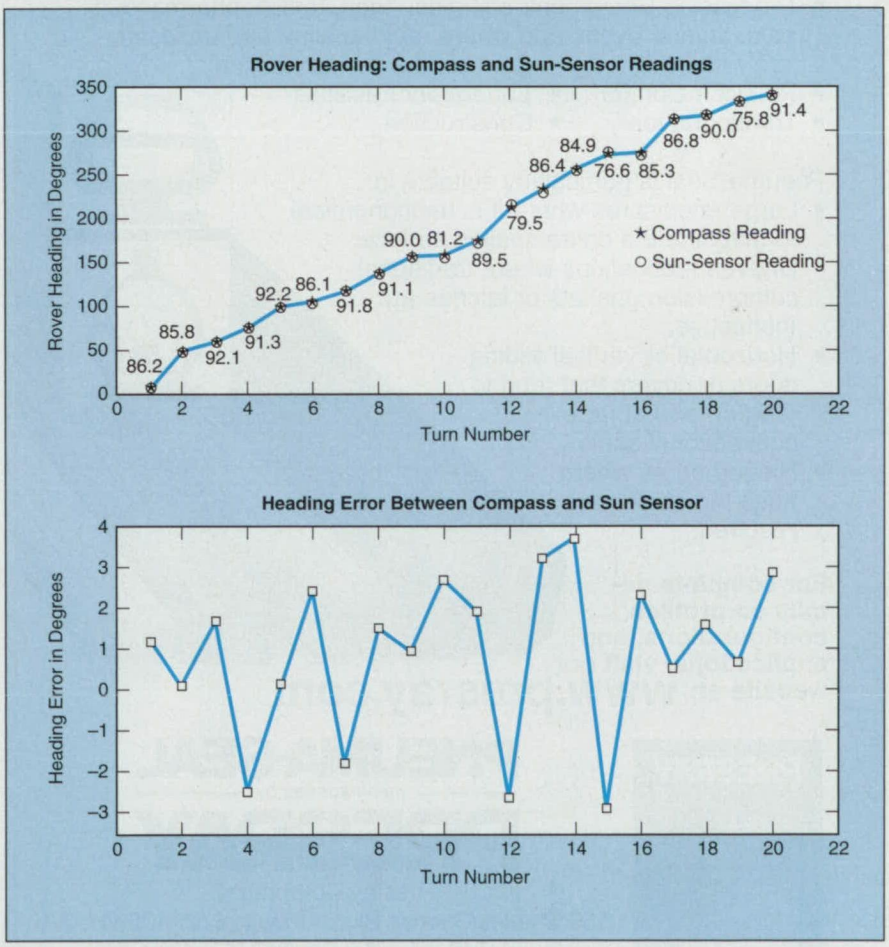

Figure 2. **Plots of Rover Heading From Compass and Sun Sensor** are illustrated. Unlike in an odometry-based heading estimation, in a Sun-sensor-based heading estimation the relative rover heading error is a constant.

with respect to true north is computed by use of the known relationship between (1) the azimuth and elevation of the Sun as computed from the ephemeris data and (2) the azimuth and elevation of the Sun as determined from the Sun-sensor data.

In a test of the Sun sensor mounted on the FIDO rover, the rover was placed on a flat surface and turned in place at angular increments of about 20°. Figure 2 depicts the headings as measured by the Sun sensor and by a magnetic compass, as well as the differences between them. The Sun sensor confidence for each reading is also indicated on the plot. The accuracy of the magnetic compass used is ± 2°. The differences between the readings can be attributed to several factors, including mechanical alignment errors of the Sun sensor, rover attitude errors, and atmospheric conditions (cloud cover).

Results of a recent FIDO field trial at Black Rock Summit in Central Nevada, in May of 2000 and several Operations Readiness Tests (ORTs) at the JPL Mars Yard using the Sun sensor have demonstrated three- to four-fold improvement in the heading estimation of the rover compared to incremental odometry. These test results helped shape the mission specifications outlined by NASA for the 2003 mission to Mars.

This work was done by Ashitey Trebi-Ollennu, Terry Huntsberger, Brett Kennedy, and Eric Baumgartner of Caltech for **NASA's Jet Propulsion Laboratory**. *For a full report on the Sun sensor visit http://fido.jpl.nasa.gov/publications.*
NPO-21182

Concept for Utilizing Full Areas of STJ Photodetector Arrays

Also, cross-talk among pixels and the number of contacts would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of designing improved monolithic planar arrays of superconducting tunnel junctions (STJs) for use as photodetectors has been conceived. These arrays would be suitable for detecting images at low light levels. They are for operation in the individual-photon-counting regime; they are used not only to detect the arrival of individual photons but also to measure the individual photon energies. As such, the STJ arrays would be compact sensors that would perform the functions now performed by bulkier equipment in the form of photomultipliers and spectrometers. Eventually, it should be possible to use STJ arrays for such demanding applications as simultaneous imaging and spectroscopy of faint astronomical objects.

Usually, an STJ photodetector contains three superconductors with different superconducting energy gaps. Photons in the energy range of interest are absorbed in the superconductor with the intermediate energy gap; this superconductor and the one with the lowest energy gap are separated by a layer of electrical insulation thin enough that photoexcited quasi-particles can tunnel (in the quantum-mechanical sense) through it. Together, the

intermediate- and lowest-energy-gap superconductors and the insulating layer between them constitute the detector junction. The superconductor with the highest energy gap is used for wiring to the other two superconductors. In a typical previously developed STJ array, separate electrical connections are made to each photodetector (see Figure 1).

Even an abbreviated explanation of the present method and the ways in which it differs from older STJ-array-design methods would greatly exceed the scope of this article because it would unavoidably include complex and interdependent details of the physics and the fabrication of STJ devices in general. For the purpose of this article, it must suffice

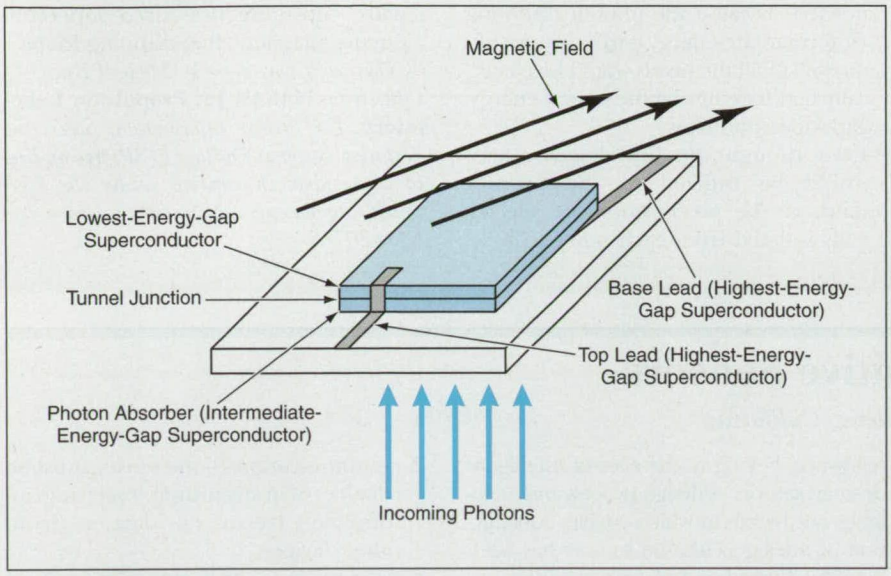

Figure 1. A **Typical STJ Photodetector** contains a tunnel junction between an intermediate- and a low-energy-gap superconductor. The electrical connections to the device are made via the base and top leads, which are made of a higher-energy-gap superconductor.

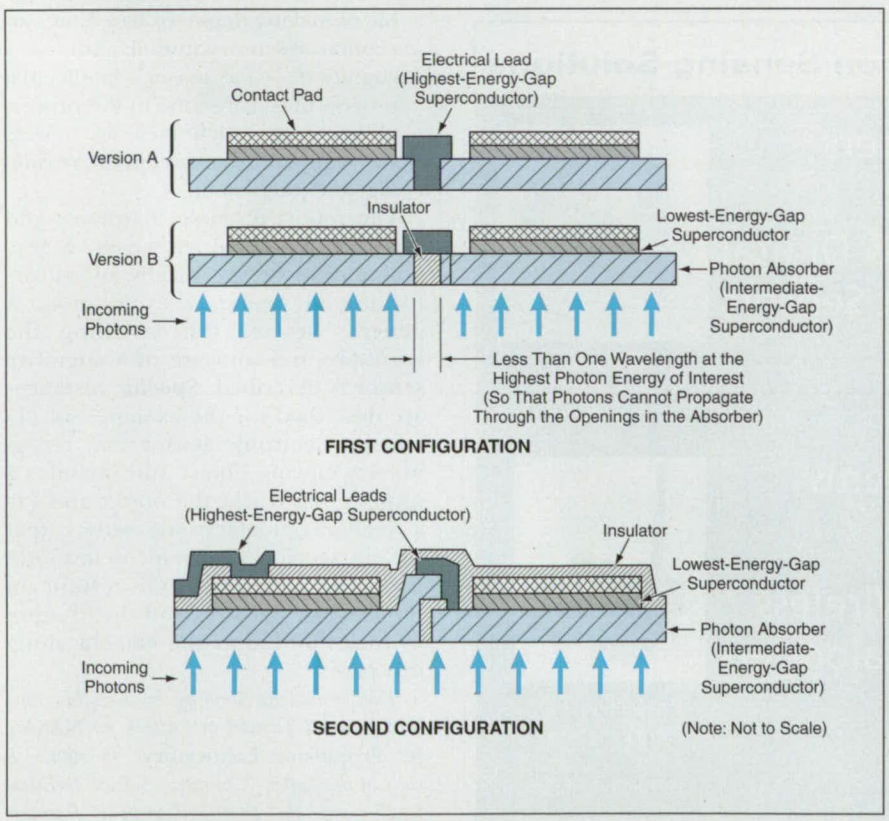

Figure 2. **Two Adjacent Pixels** of an STJ photodetector array according to the present method could be fabricated in either of two basic alternative configurations. In both configurations, the structure would behave like a solid ground plane for incident radiation at frequencies from dc up through hundreds of gigahertz, yet would present all (in the second configuration) or nearly all (in the first configuration) of its area for absorption of photons in the energy range of interest.

to summarize the major distinguishing features:

- In the previously developed STJ photodetector arrays, pixels are separated by small gaps, through which photons can pass undetected. These gaps can amount to significant fractions of total detector areas; in other words, overall quantum efficiencies are lower than they would be if full detector areas were utilized. In STJ arrays according to the present method (see Figure 2), the gaps between pixels would be either negligibly small or entirely absent; in other words, full detector areas would be utilized, thereby maximizing quantum efficiencies.
- In a typical previously developed STJ array of m rows and n columns, the number of electrical contacts necessary for individual biasing and readout of all pixels is 2mn because two contacts are needed for each pixel. In an STJ according to the present method, the number of contacts needed would be mn + 1 (slightly more than half the number previously needed) because the photon-absorbing (intermediate-energy-gap) superconductors of all the pixels would be electrically tied together by the largest-energy-gap superconductor.
- Even though the full detector area would be utilized in the present method, the pixels would be electrically isolated from each other with respect to diffusion of photoexcited quasi-particles between superconductors, so that cross-talk among pixels would be suppressed.
- Unlike at least one prior method, the present method does not call for small superconducting bridges among neighboring pixels. This is an advantage in that such bridges could, potentially, constitute undesired superconductive magnetic-flux-trapping loops.

This work was done by Michael Burns of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
NPO-20768

Development of Cognitive Sensors

NASA's Jet Propulsion Laboratory, Pasadena, California

A technical report enunciates the concept of a hierarchy of sensor classes (meaning transducers, associated circuitry, and embedded software) that have different levels of intelligence, and discusses issues pertaining to the development of sensors of the highest level of intelligence, called cognitive. The other levels, in order of decreasing intelligence, belong to the class of intelligent or smart sensors. A design process and an intelligence hierarchy which enables construction of intelligence-based sensors has been developed based on five main qualities:

1. self-knowledge — the sensor must identify its purpose and understand its operational functions;
2. communication — the sensor must be capable of transmitting/receiving information (versus raw data) to/from other devices;
3. perception — the sensor must have the ability to recognize, interpret, and understand sensory stimuli;
4. reasoning — the sensor must be capable of making decisions based on perception of sensory stimuli; and
5. cognition — the sensor's intellectual process must subscribe to the process of knowing, which includes aspects such as awareness, perception, reasoning, and judgement.

The report discusses hardware and software of a cognitive sensor in general and, more specifically, of sensors for use in planetary exploration. A generic process for designing the hardware and software of a cognitive sensor is described. Specific instances are described for the examples of (1) an optoelectronic sensor that recognizes a moving object and includes a camera that tracks the object and (2) a similar optoelectronic sensor that recognizes rocky terrain, determines the safest path across the terrain on the basis of the sizes and distribution of rocks, and aims the camera along this path.

This work was done by Ayanna Howard and Edward Tunstel of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the paper, "Cognitive Sensor Technology," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
NPO-30283

Enabling Higher-Voltage Operation of SOI CMOS Transistors

An integrated-circuit substrate would be biased against turn-on of parasitic transistors.

NASA's Jet Propulsion Laboratory, Pasadena, California

A "smart" back-gate driver circuit has been proposed to enable the operation, at voltages higher than were previously possible, of a silicon-on-insulator (SOI) complementary metal oxide/semiconductor (CMOS) integrated circuit that contains both low- and high-voltage transistors energized by corresponding low- and high-voltage power supplies. As used here, "low voltage" signifies potentials ≤3.3 V, while "high voltage" signifies potentials ≥40 V. The purpose of the back-gate driver circuit is to raise the threshold (turn-on) voltages of parasitic back-channel transistors (BCTs) that unavoidably exist in such an integrated circuit (see Figure 1). Turn-on of the parasitic transistors is unacceptable because it causes short circuits that render the integrated circuit inoperative.

In a mixed-voltage (high-voltage/low-voltage) SOI CMOS integrated circuit, the turn-on threshold voltages of parasitic BCTs are usually less than the voltage that the high-voltage transistors can withstand; heretofore, this fact has made it necessary to limit voltage ratings accordingly. The problem is com-

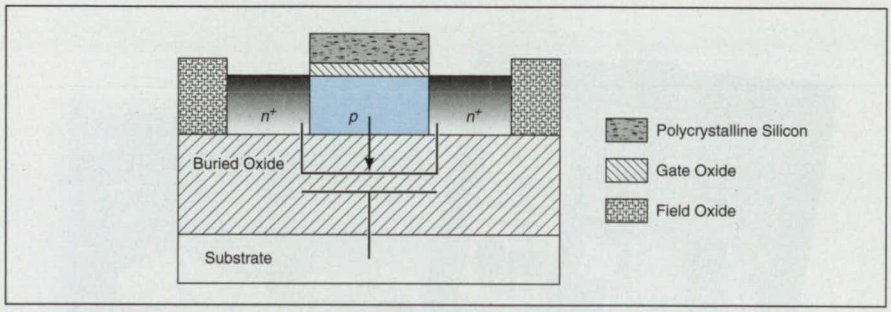

Figure 1. A **Parasitic Back-Channel Transistor (BCT)** exists under a typical low-voltage field-effect transistor (FET). If a high voltage is impressed on the source or drain of this FET, an inversion layer can form just above the buried oxide, allowing current to flow.

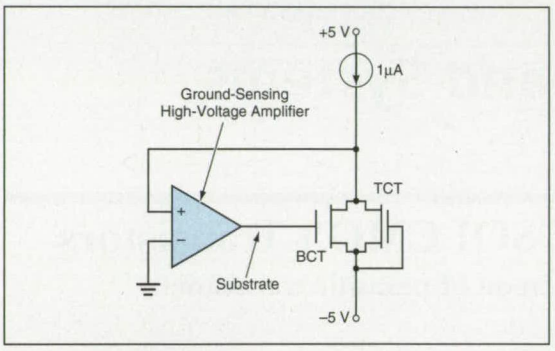

Figure 2. **The "Smart" Back-Gate Driver Circuit** would sense the turn-on voltage of one parasitic BCT and respond by biasing the substrate at a voltage that would keep all the other parasitic BCTs turned off. (Note: TCT = top-channel transistor.)

plicated by the fact that ionizing radiation causes the accumulation of positive charges in the buried oxide layer of the integrated circuit, and these charges lower the threshold voltages of the parasitic BCT.

The proposed back-gate driver circuit would apply, to the integrated-circuit substrate, a bias voltage that would ensure that the parasitic BCTs remain in the "off" state at voltages beyond those that would otherwise cause the parasitic transistors to turn on. The proposed back-gate driver circuit is characterized as "smart" because it would sense the effect of ionizing radiation on the threshold voltages and would respond by adjusting the bias voltage that it applies so as to maximize the margin of turn-off of the parasitic transistors.

Figure 2 is a simplified schematic diagram of the proposed circuit. A current of 1 μA would be forced through one n-type back-channel transistor (BCT). The source of this BCT would be biased to –5 V to ensure that its gate-to-source voltage (V_{GS}) was 5 V greater than that of any other n-type BCT on the integrated-circuit chip. Feedback would force this V_{GS} to a level that would cause a current of 1 μA to flow in this one BCT. This V_{GS} would slightly exceed the turn-on voltage of this BCT, forcing the substrate voltage to be approximately 5 V less than the turn-on voltages of all other n-channel BCTs on the chip. Exposure of the integrated circuit to aging would cause the turn-on voltages of the both the p- and n-type BCTs to shift in the same direction by about the same amount. Thus, by shifting the substrate-bias voltage in response to the sensed turn-on of one n-type BCT, the proposed circuit would maintain voltage margins against turn-on of both the remaining n-type BCTs and all the p-type BCTs.

This work was done by Mohammad Mojarradi of Caltech, Benjamin Blalock of Mississippi State University, and Harry Li of the University of Idaho for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*
NPO-20910

Estimating Antenna-Pointing Errors From Beam Squints

RCP and LCP beams are received at different levels when aim is not perfect.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of estimating the pointing error of an offset-conic-section reflector antenna equipped to receive in both right circular polarization (RCP)

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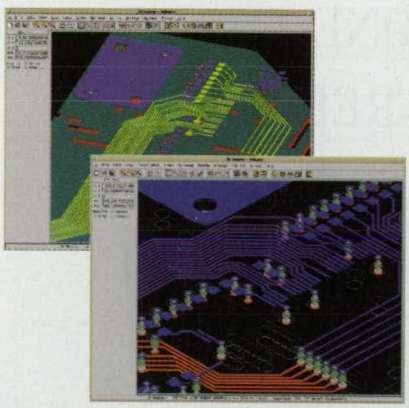

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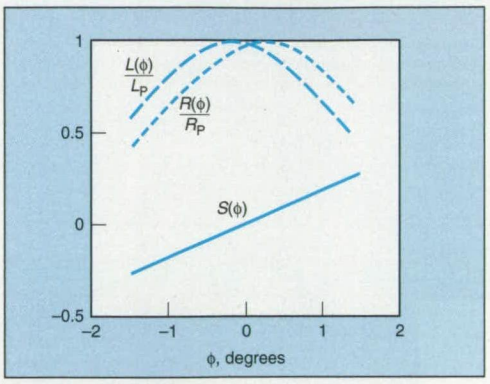


These Curves Were Calculated for Gaussian RCP and LCP beams 3° wide, with 0.3° squint between beams.

and left circular polarization (LCP) exploits a phenomenon that, heretofore, has been regarded as a minor nuisance. The phenomenon in question is a misalignment between RCP and LCP beams and manifests itself as opposing squints of the beams. The method enables the generation of pointing-error estimates at high rates for use as feedback in high-bandwidth antenna tracking-control systems, without need for the complex radio-frequency circuitry of monopulse or traditional sequential-lobing antenna tracking-control systems. The method was conceived especially to be used at terrestrial stations to track LCP and RCP signals transmitted by satellites.

When an antenna is mispointed in one direction, the RCP signal normalized by its peak value is stronger than the corresponding normalized value of the LCP signal. When the antenna is mispointed in the opposite direction, the normalized LCP signal is the stronger one. Zero pointing error in this context is defined as the antenna-aiming direction for which the normalized RCP and LCP signal levels are equal. The difference between normalized signal levels can be characterized as an S-curve function of the pointing error; this curve is given by

$$S(\phi) = 2\{[R(\phi)/R_P] + [L(\phi)/L_P]\}/\{[R(\phi)/R_P] - [L(\phi)/L_P]\},$$

where ϕ is the angular pointing error; $R(\phi)$ and $L(\phi)$ denote the levels of the RCP and LCP signals, respectively, at ϕ; and R_P and L_P denote the peak levels of these signals. The figure presents an example of the normalized signal levels and of the S-curve function for small pointing-error angles. The S-curve function can be inverted so that the pointing error can be estimated from the normalized signal levels.

In the present method, one obtains the normalized signal levels from measurements of levels and differences between levels of satellite signals received through the antenna while switching rapidly (electronically) between the reception in RCP and LCP. "Satellite dish" antennas equipped with circuitry to receive both RCP and LCP and capable of rapid switching between RCP and LCP are commercially available. This method of reception amounts, in effect, to a method of electronic sequential lobing. The faster the electronic switching between RCP and LCP, the greater the bandwidth of the pointing-error signal.

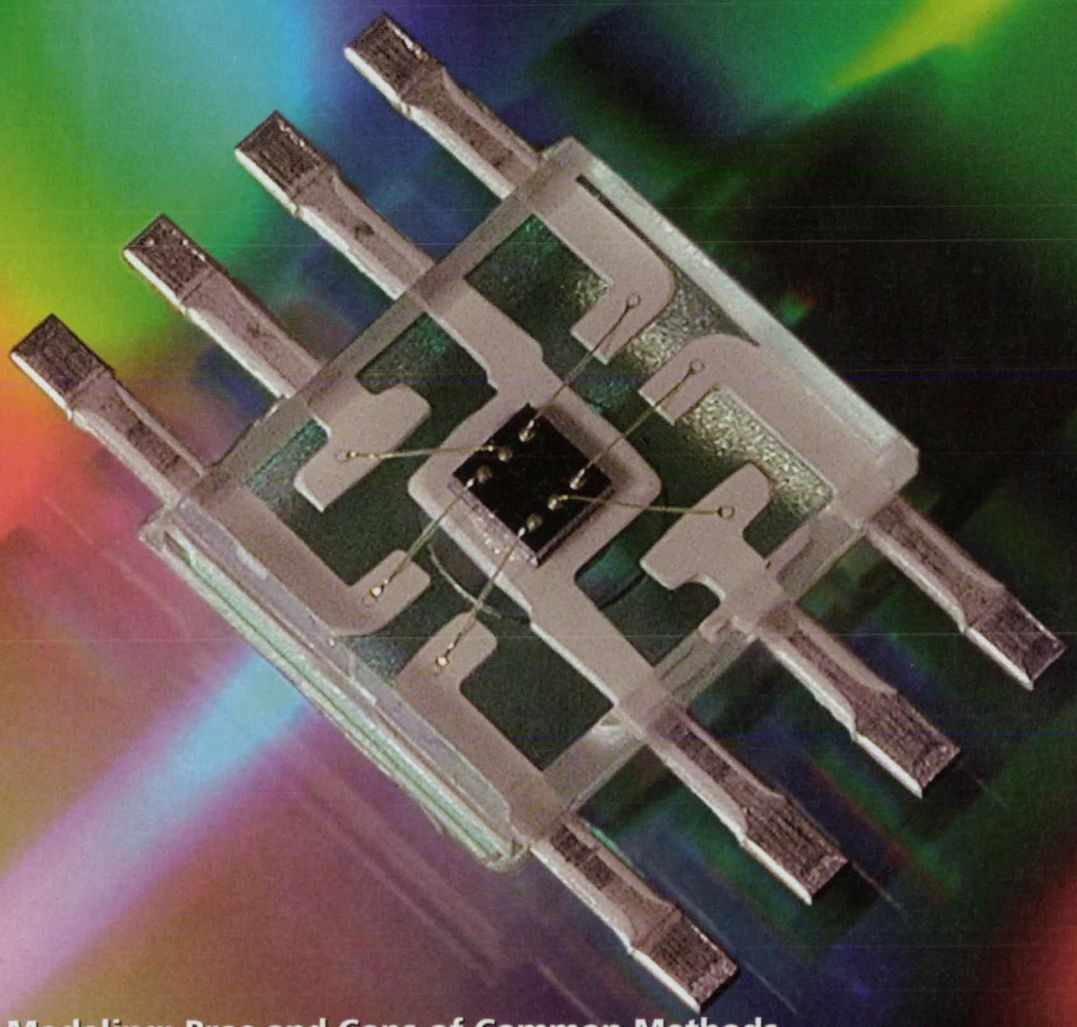
This work was done by Arthur Densmore of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL; 818-354-7770. Refer to NPO-19938.

April 2002

PHOTONICS Tech Briefs

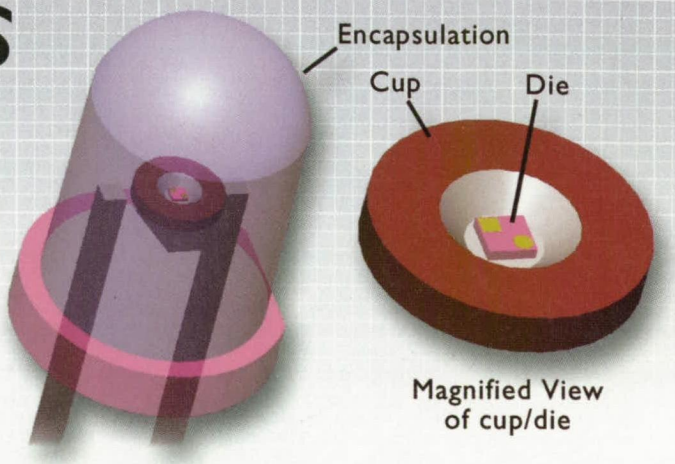
PHOTONICS SOLUTIONS FOR THE DESIGN ENGINEER



Cover photo courtesy of Hamamatsu Corporation

LED Modeling:

Pros and Cons of Common Methods



The three key opto-mechanical elements of most LEDs.

Light Emitting Diodes (LEDs) offer several advantages over incandescent, fluorescent, and discharge light sources, including longer lifetime, smaller size, and greater mechanical ruggedness. Continuing developments in LED technology are producing sources with increased output power and electrical efficiency as well as a wider range of colors, including so-called "white light" LEDs. Consequently, LEDs are replacing traditional light sources in numerous illumination applications, from traffic signals to instrumentation. As with any light source, effectively utilizing LEDs in an optical system requires the ability to accurately model their output characteristics with software.

There are three key opto-mechanical elements of most LEDs. The first is the LED die itself. The second is a metal cup in which the die sits. This cup provides one of the electrical contacts to the die, acts as a heatsink, and also works as a reflector to redirect light exiting the sides of the LED die. The final part is any integral lens or encapsulation. LEDs range from bare, cuboid emitters, to more complex designs that may include multiple emitters, integral lenses, and phosphor layers to alter their spectral output (color).

Modeling Tradeoffs

In designing optical systems containing LEDs, the goal at any stage is to use the simplest model that adequately predicts the behavior of the system. A simple model is desirable because LEDs present considerable optical complexity and it is not uncommon to trace millions of rays in each iteration of an illumination system design and analysis. Of course, what constitutes an "adequate prediction" of performance can vary. A simpler model might suffice for a feasibility study, while a more rigorous approach may be needed for the actual design and optimization of the final optical system.

The most elementary way to effectively model an LED is as a point source whose output is apodized (varied in a systematic way) as a function of angle. The apodization is usually derived from manufacturer-supplied data. This simple model is straightforward to construct and ray trace in most optical or illumination design programs.

The point source model is most useful for doing first-order system design. This includes roughly determining values for the focal lengths, f-numbers, element sizes, and component locations. The point source model also enables first-order calculation of the optical system's collection efficiency. However, the point source model is inadequate for performing any analysis in the near field of the LED, where effects due to the finite source size are most pronounced.

A significant increase in accuracy can be obtained by modeling an LED as an extended source, where the angular output distribution and any spatial nonuniformities are independently specified. At Optical Research Associates (ORA), a model of this type, in which the angular distribution is constrained to be the same from every point on the surface, is called an "apodized emitter."

The apodized emitter model is easy to construct and still simple enough to enable rapid ray tracing. For example, it can be specified in several different ways in ORA's illumination design and analysis software package, LightTools. These include applying apodization files directly to a source, creating a superposition of several sources, or even illuminating a scattering surface with collimated rays.

While still generic, the apodized emitter approach is sufficiently accurate for many uses, and is probably the most popular LED software model. Typical systems applications include light pipes, mixing rods, large core, plastic optical fibers, instrumentation lighting, tail lamps, and pillow optics.

The angular distribution of an apodized emitter model can be matched to manufacturer's data, and thus usually specified with good accuracy. However, determining source size, spatial variation, and position within the package is not always so straightforward; this makes it difficult to know the precise accuracy of the model. Errors in specifying these parameters have the most pronounced impact when analyzing systems with limiting apertures.

The next step in model complexity is to explicitly include representations of the LED's various component parts (e.g. die, cup, and lens). ORA terms a model

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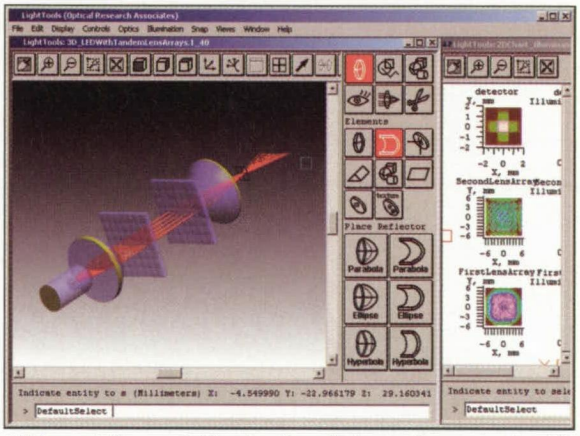
composed of angularly and spatially apodized point sources, surface sources, and volume sources — together with optomechanical constructs — a "geometry + emitters" model.

This approach enables several source-specific characteristics to be examined in some detail. Examples include the reflective characteristics of the cup, and the refractive, reflective, and scattering properties of the lens and/or encapsulation. Incorporating "second order" effects, such as spurious reflections from parts of the LED package, is important because these can sometimes determine the real-world success or failure of a system.

Modeling the source as a series of discrete elements also facilitates answering "what if" questions about the system. For example, the reflection from a specific surface might be turned on or off to determine its significance, or the position of a particular LED component might be altered to assess the impact of part-to-part dimensional variations on system performance.



LED modeling and illumination design software — in this case, ORA's LightTools — enables ray tracing of complex optical systems. This condensing system consists of tandem lenses and two 7 × 7 lenslet arrays.

Unfortunately, the "geometry + emitters" model is time-consuming to create, and may require numerous iterations to get the model output to closely match the real LED output at all angles. This time can be mitigated through the use of optimization, but the level of detail adequate for one application may be insufficiently accurate for another, so the time investment to develop the model may not be preserved.

Measurement-Based Models

An accurate empirical approach to source modeling has been developed by Radiant Imaging. Their system utilizes a CCD camera, mounted on a computer-controlled, two-axis goniometer. This system scans an emitting source from all angles, and records the actual luminance distribution at each source view. The files created by the Radiant Imaging system can then be used in most illumination design programs to generate random ray sets that precisely match the angular and spatial output distributions of the source.

Radiant Imaging source models provide two primary advantages. First, they require very little or no time to create (if they are purchased directly from Radiant Imaging, which has a library of many different sources on file). Second, they are completely accurate, automatically taking into account all source characteristics, such as the effects of defects in the plastic lens.

The drawback of the Radiant Imaging approach is that each model is of only one source sample. If the scanned source is not a "typical" representative of that source type, then neither is the model. Also, these source models cannot be altered, so there is no capability for adjusting source parameters or isolating the impact of specific source characteristics (e.g. scattering by the cup). Furthermore, the Radiant Imaging approach provides just a ray source to the program, not an optomechanical construct with which a program can interact. Thus, there is no ability to analyze rays that re-enter the source after hitting other parts of the optical system.

In conclusion, developments in LED and other source technologies, together with the rapid proliferation of displays, have created an increasing market for more complex and sophisticated illumination systems. A new generation of more powerful illumination system design programs has been created to meet this demand. However, using these programs successfully and cost effectively still requires an ability to identify and accurately model the most significant source characteristics.

This article was written by William Cassarly, Ph.D., Optical Research Associates, 3601 Green Road, Suite 104, Beachwood, OH 44122-5719. Contact the author at: 216-831-0780; Fax 216-831-0790; or email: billc@opticalres.com. Visit ORA at www.opticalres.com.

CLEO 2002

Provides Education and Cutting Edge Technology

Interested in the latest advances in lasers and electro-optics? Then you probably already know about CLEO 2002 (Conference on Lasers and Electro-Optics) taking place May 19-24, 2002 at the Long Beach Convention Center in Long Beach, California. Again this year, the 10th Annual Quantum Electronics and Laser Science Conference (QELS) will run in conjunction with CLEO. QELS addresses research in lasers, nonlinear optics, and the fundamental laser spectroscopy of atoms and condensed matter. Together CLEO/QELS 2001 attracted 6,500 attendees to the Baltimore Convention Center in Baltimore, Maryland. Attendees include representatives from a wide range of industries including communications, medical, optical components, analytical instrumentation, aerospace, imaging, and precision manufacturing.

Exhibition and Conference

Over 350 companies will be showcasing the latest technologies from May 21-23rd at the CLEO exhibition. Hands-on workshops and demonstrations at exhibitor booths allow attendees to gain a better understanding of fiber-optic technologies, applications, and research while making valuable contacts in the industry.

Running from May 19-24th, the technical conference offers a joint plenary session, special symposia, tutorials, invited papers, selected papers and short courses covering a wide range of topics. CLEO's technical program emphasizes applied physics, engineering, and lasers and electro-optics usage while QELS highlights fundamental science and the use of lasers and electro-optics in scientific research.

Registration

Want to attend CLEO 2002? You can register for either the full technical program or only short courses. Both registration types include admission to the exhibition. Complete your advance registration online, by fax, or via regular mail. Payments must be submitted with the registration form — available online in PDF format. For additional information visit www.cleoconference.org.

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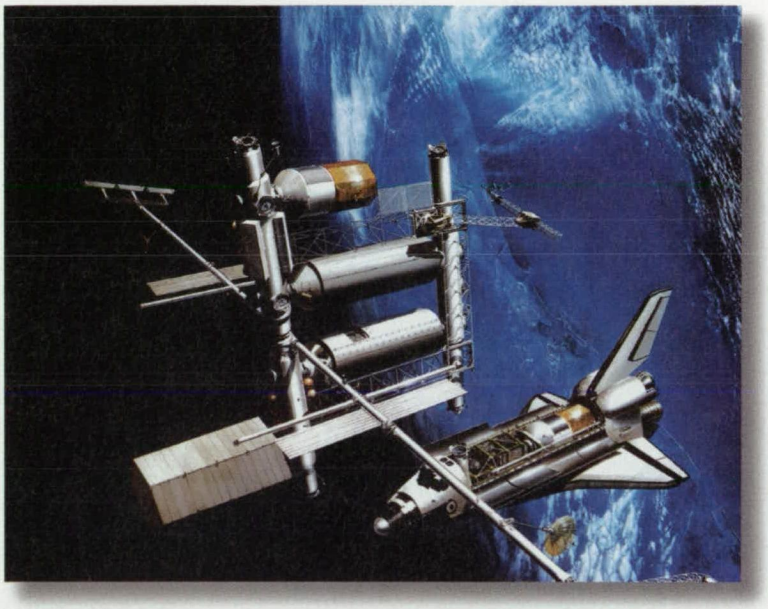

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Product Guide: Optical Design Software

Software continues to be a pioneering field and one of the fastest growing sectors of the international economy. Over $150 billion a year in revenue is generated by software with approximately one quarter stemming from development tools, according to Hoovers.com.

Optical design software enables innovation by providing a medium for improving existing technologies and discovering new ones while frequently speeding up time-to-market and reducing overall costs. Engineers use these programs to design, model, and analyze optical devices and systems.

This month's Product Guide features software offerings segmented into three general categories: optimization, ray-trace, and computer-aided design (CAD). Optimization — the process of taking an initial design and altering it to minimize errors — is considered to be the focus of optical design packages. This list extends beyond the traditional definition to include ray-tracing (evaluation) programs and CAD packages (drawing). Combining software packages from these three categories can create a broader range of integrated capabilities. Source companies should be contacted for detailed compatibility information.

This list is representative of the many companies and software offerings available to meet the needs of the optical industry. Along with the product name and a brief description, we have provided primary system requirements. Readers can obtain detailed pricing and capability information by visiting the web site shown in the chart or contacting the source company directly.

Company	Product	Summary	Processors	Operating Systems
Optimization				
Acme Optics www.acmeoptics.com	Roadrunner	Command driven design and analysis program. Available versions: Standard & LT.	Pentium II or higher	Windows95/98/ME/NT4/00
Diginaut www.diginaut.com	ADOS	Defines new optical systems, displays and performs analysis of data, and optimization.	Pentium (II or higher recommended)	Windows 95/98/ME/NT4/00
Focus Software www.focus-software.com	ZEMAX	System conceptualization, design, optimization, analysis, tolerance, and documentation of sequential & non-sequential imaging and non-imaging systems. Available versions: SE, XE, & EE.	Pentium III (300MHz or higher)	Windows 95/98/ME/XP/NT4/00
Grating Solver Development Co. www.gsolver.com	GSOLVER© V4.20	Performs diffraction for arbitrary periodic grating structures including all polarizations.	Pentium and higher	Windows 95/98/NT4/00
Lambda Research www.lambdares.com	OSLO®	Primary use: Determination of the optimum sizes & shapes of the elements in optical systems, simulation of optical system performance, and and to development of specialized software tools for optical design, testing, and manufacturing. Available versions: Premium, Standard, & Light.	Pentium or higher	Windows 95/98/NT/00, HP-UX, or Solaris
Linos Photonics GmbH http://www.linos-photonics.de/en/homefr2.html	WinLens	Design and analysis of optical systems. Creates systems with LINOS Photonics and custom components.	Pentium (100 MHz minimum)	Windows 95/98/NT
O++ www.oplusplus.com	APILUX	Design software dedicated to photometricapplications, optical design and multi-channel systems.	Pentium 90	Windows 95/98/NT/00
Optical Research Associates www.opticalres.com	CODE V®	Analysis, optimization, illumination calculations, and fabrication support.	Celeron, Pentium, Pentium PRO, Pentium II,III, or IV	Windows 98/ME/NT4/00
Optiwave Corp. www.optiwave.com	OptiSystem	Simulation package for the design, testing and optimization of virtually any type of optical link in the physical layer of a broad spectrum of optical networks.	Pentium or higher	Windows 98/ME/XP/NT4/00
Photon Design www.photond.com	FIMMWAVE	A generic, fully vectorial mode finder for 2D waveguide structures as well as single and multicore fibers.	PC: Pentium II 300MHz or better recommended	PC: Windows 95/98/NT/00 or UNIX: SUN-solaris2.5.1 or later
Photon Design www.photond.com	FIMMPROP-3D	Bidirectional 3D propagation tool for component design.	Pentium II (300 MHz or higher)	PC: Windows 95/98/NT/00 or UNIX: SUN-solaris 2.5.1 or later
Radiant Imaging www.radimg.com	ZELUM	Illumination System Design Software for ZEMAX. Models, designs, and analyzes optical systems such as projectors, LED's, or other light sources.	Pentium or higher	Current version of Windows or Windows NT, also requires current version of ZEMAX

Company	Product	Summary	Processors	Operating Systems
Rsoft Design Group, Inc. www.rsoftinc.com	LinkSIM™	Simulation softwaretool. Design and analyze links in optical telecommunication and broadband fiber optic systems using sources, components, and fiber effects.	Pentium or higher	Windows 95/98/ME/NT/00, UNIX: requires Motif and X11R6.
Sky Scientific www.skyscientific.com	dbOptic	Design Database Program. Creates and analyzes systems with up to 99 surfaces including spherical and aspherical surfaces, flats and irises.	80486 processor (Pentium recommended)	Windows 95/98/ME/XP/NT/00

Ray-Trace

Breault Research Organization www.breault.com	ASAP™	Non-sequential ray tracing program for modeling physical optics, imaging, and illumination systems. Available versions: Basic, Pro, CAD, ELTM, & Optical.	Pentium (200 MHz)	Windows 98/ME/XP/NT4/00
Lambda Research www.lambdares.com	TracePro® 2.4	Ray tracing for illumination analysis, optical analysis, radiometry analysis, and photometry analysis. Available versions: RC, LC, Standard, & Expert.	Pentium II 400 MHz	Windows 95/98/NT/00
OptiCAD Corp. www.opticad.com	OptiCAD®	Models non-sequential, stray light, and illumination optical systems. Includes capability to do unconstrained ray tracing considering reflection, refraction, surface & bulk scattering & polarization.	Pentium, Pentium Pro/II/III	Windows 95/98/NT or later
RayCAD, Inc. www.raycad.com	RayCAD	Opto/mechanical design tool. Performs analysis on arbitrarily placed optical components, with the capability to do unconstrained ray tracing considering, reflectionrefraction, surface & bulk scattering & polarization. Requires AutoCAD®.	486DX or greater	Windows 95 or later
Science Lab Software www.optics-lab.com	Optics Lab	Non-sequential ray tracing program that provides models for optics, includes automatic optimization and allows simulation of opto-mechanical devices with control signals developed from simulated detector outputs.	Pentium II or higher	Windows 95/98/ME/NT4/00
SCIOPT Enterprises www.sciopt.com	Optec-IV	General optical systems design (lens design / raytrace) program.	Pentium or higher	Windows 95/98/ME/XP/NT/00

CAD

Autodesk Corp http://usa.autodesk.com	AutoCAD®	2D and 3D design and drafting platform that automates design tasks and provides digital tools. Serves as foundation for programs such as RayCAD.	Pentium II or AMD K6-II 450 MHz	Windows 98/ME/XP/NT4/00
Optical Research Associates www.opticalres.com	LightTools®	Modeling of optical components, light sources, and mechanical parts. Packaging studies and stray light analysis. Available versions: Core, Illumination, & Data Exchange.	Celeron, Pentium II, III, or IV (450 MHz or higher) *Intel PCs not supported	Windows 98/ME/NT4/00
Optikwerk www.optiwork.com	OptiKwerks®	Optics and laser CAD package for designing laser systems & resonators, Illumination & non-imaging systems, and conventional optical assemblies. Available in Standard & Pro.	80486 or Pentium	Windows 95/98/ME/NT/00
Optiwave Corp. www.optiwave.com	OptiFDTD	CAD package for advanced passive and active photonics components.	Pentium (900 MHz or higher)	Windows 98/ME/NT4 or later
Rsoft Design Group, Inc. www.rsoftinc.com	BeamProp™	CAD and simulation program used to design integrated and fiber optic waveguide devices and circuits based on the beam propagation method (BPM).	Pentium II or higher	Windows 95/98/NT4 or later, UNIX versions require Motif and X11R6
Rsoft Design Group, Inc. www.rsoftinc.com"	FullWAVE™	Integrated CAD and simulation program for design of photonic devices.	Pentium II or higher	Windows 95/98/NT4.0 or later, UNIX versions require Motif and X11R6

Technologies of the Month

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Projection Display Apparatus Offers More Brightness and Higher Contrast

A new projection-type display apparatus comprises a light source optical system with an anisotropic luminance distribution, a transparent-scattering display element for controlling light emitted from the light source optical system, and a projection optical system with an aperture that projects the transmitted light. The aperture has a non-circular opening in the vicinity of the focal point of the transmitted light of the transparent-scattering type display element. This provides a brighter projection image, and less optical loss than using a twisted nematic (TN)-type liquid crystal display (LCD) element.

The new projection-type display can be used in large-screen and projection televisions, for large-screen computer monitors and simulators, and for monitors in industrial control rooms.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/display.html
Email: nasatech@yet2.com
Phone: 617-557-3837

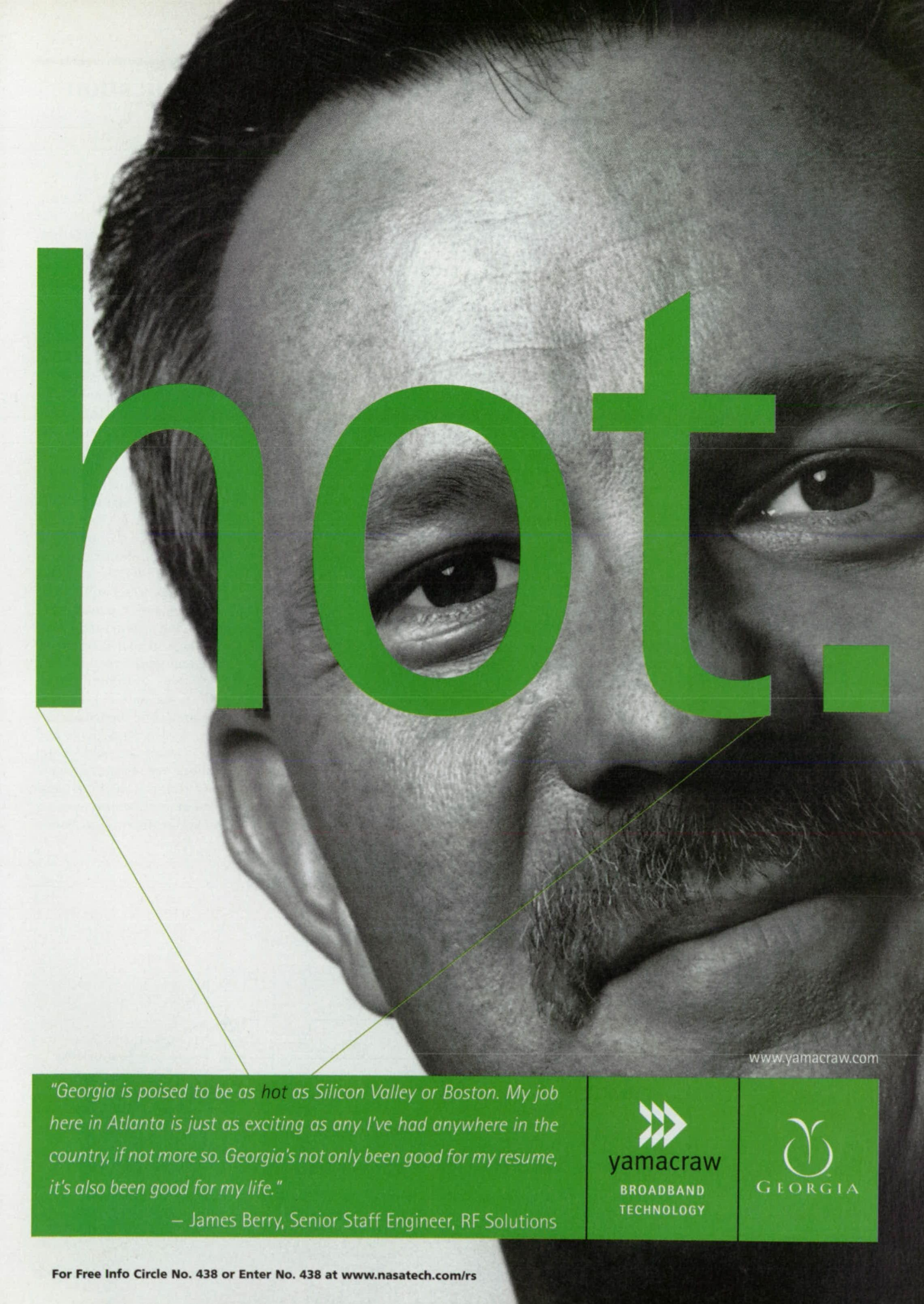
Laser System Measures Curvature of Smooth Surface

AMROC! (Automatic Measurement of Radius Of Curvature) is a new measurement system that determines the curvatures of smooth surfaces such as contact or spectacle lenses, all the way up to astronomical mirrors. Like other optical instruments, AMROC uses lasers to avoid having to place a hard test surface against the surface under test. The advantage of the new system over previously available non-contact systems using simple reflective measurements is that it can measure both spherical and aspheric surfaces.

The process involves placing the test object under a scanning laser system, or allowing the object to move past the laser system. The reflections from the surface are then measured and the curvature of the surface is determined. AMROC is capable of calculating the curvature of several surfaces in the same object, as long as the refractive indices of the materials are known.

The twin-beam unit consists of a handheld optical front end with a separate computer and power supply. The instrument consists of two diode laser sources that emit in the visible range of red wavelengths, and provides an indication to the operator of where the measurements are being made. Each laser is switched on and off in anti-phase; when one is on, the other is off. For transparent items such as lenses, discrete element detectors such as Charge Coupled Devices (CCDs) can be used.

Get the complete report on this technology at:
www.nasatech.com/techsearch/tow/amroc.html
Email: nasatech@yet2.com
Phone: 617-557-3837



Adaptive Multiplexing for Free-Space Optical Communication

Wavelength- and code-division multiplexing would be utilized for security and improved performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

"Laser-based adaptive wavelength division multiplexing and code division multiplexing" (LAWDM-CDM) is the name of a method that has been proposed to increase security, signal-to-noise ratios (SNRs), redundancy, and adaptability in free-space optical communications. The need for this or a similar method arises as follows:

- In free-space optical communications, various phenomena can affect the propagation and reception of laser beams; these phenomena include jitter of transmitter and receiver platforms and atmospheric attenuation and distortion of laser beams. In a conventional free-space optical communication system, data are transmitted at a constant rate that is not changed to adapt to changing conditions; consequently, for example, a sudden change in weather can disable the free-space optical link, causing loss of data.
- Free-space optical communications are not entirely secure because laser beams can propagate beyond intended receivers and therefore can be intercepted by unintended parties.

In addition to wavelength-division and code-division multiplexing, LAWDM-CDM would involve the use of multiple transmitting apertures, adaptive control of the data-transmission rate and the transmitter power, and other advanced techniques as described below.

- Eavesdropping would be reduced by using adaptive optics to reduce atmosphere-induced beam spreading and by tailoring the transmitter power to be low enough to minimize propagation beyond the intended receiver yet high enough to reach the intended receiver with an acceptably high SNR. One could choose wavelengths with limited atmospheric transmission to reduce the range of the optical signal.
- Wavelength hopping and code-division multiplexing would make it difficult for an unintended recipient to decode a signal.
- Under adverse atmospheric conditions, the bit rate would be reduced to keep the bit-error rate below a specified maximum acceptable level.
- At the transmitter, laser light back-scattered by the atmosphere would be detected in a lidarlike subsystem, the output of which would be utilized in an algorithm that would select the optimum bit rate and power level.
- Multiple apertures at a transmitter would help to reduce the effect of the scintillation.
- Time-spread code-division multiplexing would enhance reception.

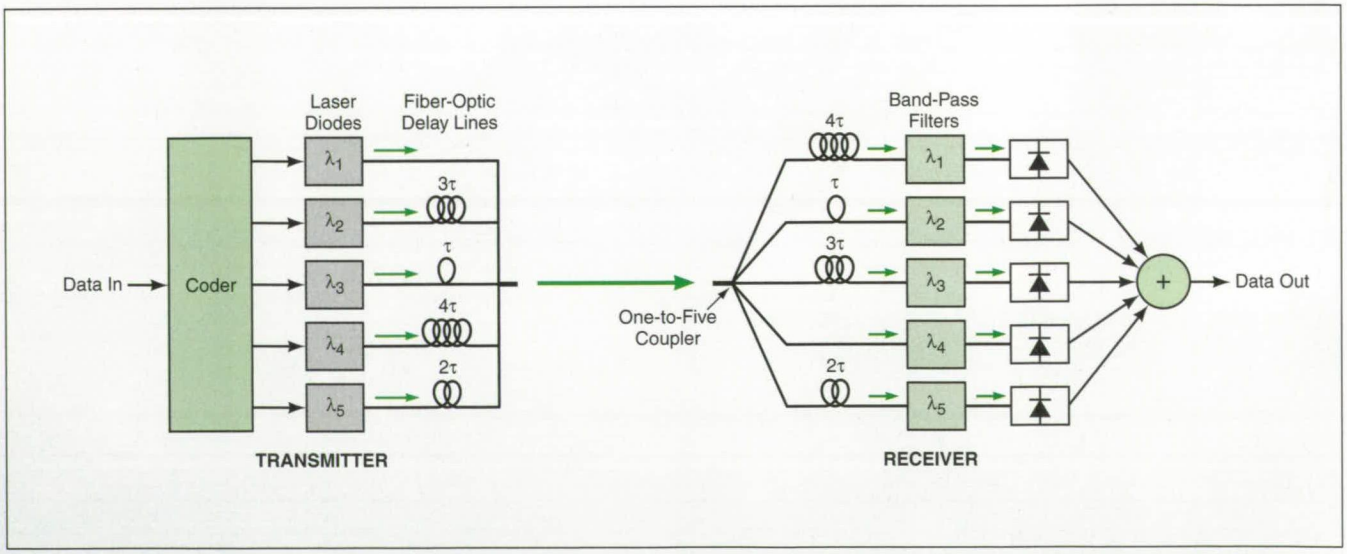
The figure illustrates an example of a simple system that would utilize a combination of wavelength-division multiplexing and time-spread code-division multiplexing to increase security. In the transmitter, a code sequence comprising five parallel bits during each bit period would control the simultaneous generation (for "1") or nongeneration (for "0") of pulses by five laser diodes, each operating at a different one of five wavelengths (λ_1 through λ_5). Before being launched for propagation to the receiver, the signal in the ith wavelength channel would be delayed by an amount τ_i, which would be a unique integer multiple of the bit period, τ. The longest delay would be 4τ for λ_4.

In order to be able to decode the signal properly, the receiver would have to be equipped with delay lines complementary to those in the transmitter: In the receiver, the incoming signal would be demultiplexed into the five wavelength channels and the signal in the ith channel would be delayed by $4\tau-\tau_i$, so that the total of transmitter and receiver delays in each channel would be 4τ and, hence, the five signals would come out of the receiver simultaneously, just as the original five bits went into the transmitter simultaneously.

Provided that the differences among the five wavelengths were sufficiently large and the transmitter power were properly adjusted, this system would offer a security advantage in that it would be difficult for an unintended recipient to detect its operation. Moreover, eavesdropping on any single wavelength would not enable one to decode the message.

This work was done by Sir B. Rafol and Keith Wilson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Electronic Components and Systems category.*

NPO-20890



This **Free-Space Optical Communication System** would implement a combination of wavelength-division and time-spread code-division multiplexing.

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Magnetically Suspended Optical Chopper Wheel

Magnetic bearings offer long life at high speed, without lubrication or wear problems.

Goddard Space Flight Center, Greenbelt, Maryland

A magnetically suspended, motor-driven light-chopping wheel has been developed as an alternative to a traditional light-chopping wheel suspended on ball bearings. This chopper (see figure) is designed to satisfy application-specific requirements to fit into a small volume, dissipate relatively little power, modulate light with only small errors, and have a long operational life (at least 5 years) at a speed of 5,000 rpm. Relative to ball bearings, the magnetic bearings in this chopper are subject to no wear, and unlike ball bearings, magnetic bearings present no need for lubrication.

This chopper satisfies additional stringent requirements for full redundancy of magnetic-bearing coils, motor coils, and sensors. The magnetic bearings are controlled, in all six degrees of freedom of the chopper wheel, by use of a digital signal processor (DSP) operating in conjunction with sensor and driver electronic circuits. The DSP and the other circuitry are contained on a printed-circuit board with overall dimensions of 6 by 8 in. (≈ 15 by 20 cm).

Unique features of the design and its implementation include the following:

- Homopolar magnetic bearings are made in a novel (patent pending) configuration to minimize rotational losses;
- High-resolution, highly linear optical position sensors with feedback (patent pending) provide automatic gain and offset control;
- An ironless stator motor assembly, optimized to minimize eddy-current losses, is fabricated by use of a modified printed-circuit-board manufacturing technique;
- The DSP is used to compute 6-axis classical and adaptive control algorithms; and
- At the time of reporting the information for this article, this chopper is the smallest known mechanism that incorporates fully active magnetic bearings with full redundancy of electrical components.

This specific application for which this chopper has been developed is an infrared-sensing instrument aboard an Earth-observing satellite. Magnetic-bearing systems like those of this chopper, but larger, are under consideration for use in diverse outer-space and terrestrial applications in which rotating wheels would be used to store angular momentum and/or kinetic energy.

This work was done by Ken Blumenstock, Carlos Bernabe, Carlos Hernandez, Ken Lee, Joe Schepis, Clarence Johnson, Maurice Lewis, and Paul Haney of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP) **free on-line at www.nasatech.com/tsp** under the Machinery category.*

GSC-14323

This **Optical Chopper Wheel** is magnetically suspended, offering certain advantages over traditional light-chopping wheels, which are suspended on ball bearings.

Fiber-Optic Rotary Joint for Passing High-Definition Video

Fiber-optic transmission overcomes the bandwidth limitation of slip rings.

Dryden Flight Research Center, Edwards, California

A video camera has been integrated with a tracking pedestal (see figure) for tracking of aircraft and spacecraft. The camera is of a high-definition (1,280 × 720 pixels), progressive-scan, 60-frame-per-second digital type that conforms to NASA Standard 2818 (Digital Television Standards for NASA, a copy of which can be obtained via the Internet at http://www.hq.nasa.gov/office/cio/standards/2818.pdf). The camera is mated to a 13.5-to-1,755-mm zoom lens, making it possible to track vehicles at distances up to 100 miles (≈160 km).

The digital video signal, at a data rate of 1.5 Gb/s, is transmitted from the camera via an optical fiber. The signal passes through a fiber-optic rotary joint (FORJ) through the horizontal axis of rotation of the pedestal. The FORJ contains two fiber-optic conductors, each capable of a data rate of 3 Gb/s, that are used to pass high-definition video and camera-control signals. All other power and control signals pass through standard copper slip rings in the pedestal.

The FORJ and the pedestal are commercial products. The pedestal was modified to accept the FORJ. The mod-

ification included the fabrication of a yoke assembly to enable rotation of the upper half of the FORJ with the rotation of the upper half of the pedestal. The FORJ was originally produced for use in submersible remotely operated vehicles with rotating manipulator arms. The high-bandwidth digital video signal cannot pass through conventional copper slip rings of the unmodified tracking pedestal. The modification of the tracking pedestal to work with the FORJ makes it possible to use high-definition video for tracking experimental aircraft and spacecraft.

This work was done by Tony Trent of **Dryden Flight Research Center**. *For more information, contact Dryden's Commercial Technology at (661) 276-3689.*
DRC-01-28

Camera Integrated With Tracking Pedestal

Fiber-Optic Rotary Joint

The **Integration of the Camera With the Tracking Pedestal** was made possible by modification of the pedestal and development of the FORJ.

Mesoscopic Steerable Mirror

This mirror could be slewed rapidly or rotated in small angular increments.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed lightweight, micromachined, multiaxis-steerable mirror would have mesoscopic dimensions. Its steering function would involve mesoscopic positional excursions of its support points and would be characterized by rapid slewing and moderate angular precision.

The mirror, its supporting structures, and its steering mechanisms would be fabricated in a four-layer polycrystalline-silicon surface-micromachining process. The mirror would be triangular and would be supported at its corners. The steering mechanisms and supporting structures connected to two of the corners would include electrostatic comb drives, reduction gear trains, gear-driven translation racks, hinged beams, and flexures (see figure).

In one example design, the electrostatic comb drives would operate in four-phase cycles. For each such cycle, a 19-tooth pinion gear would undergo one revolution. The thrust of each comb drive would be ≈1 μN and could be applied rapidly enough to sustain rotational speeds up about 4,000 revolutions per second. Two tandem gear trains would reduce the translation to 1.66 μm per pinion rotation or, equivalently, 0.415 μm per phase step of an electrostatic comb drive, and would increase the torque proportionally.

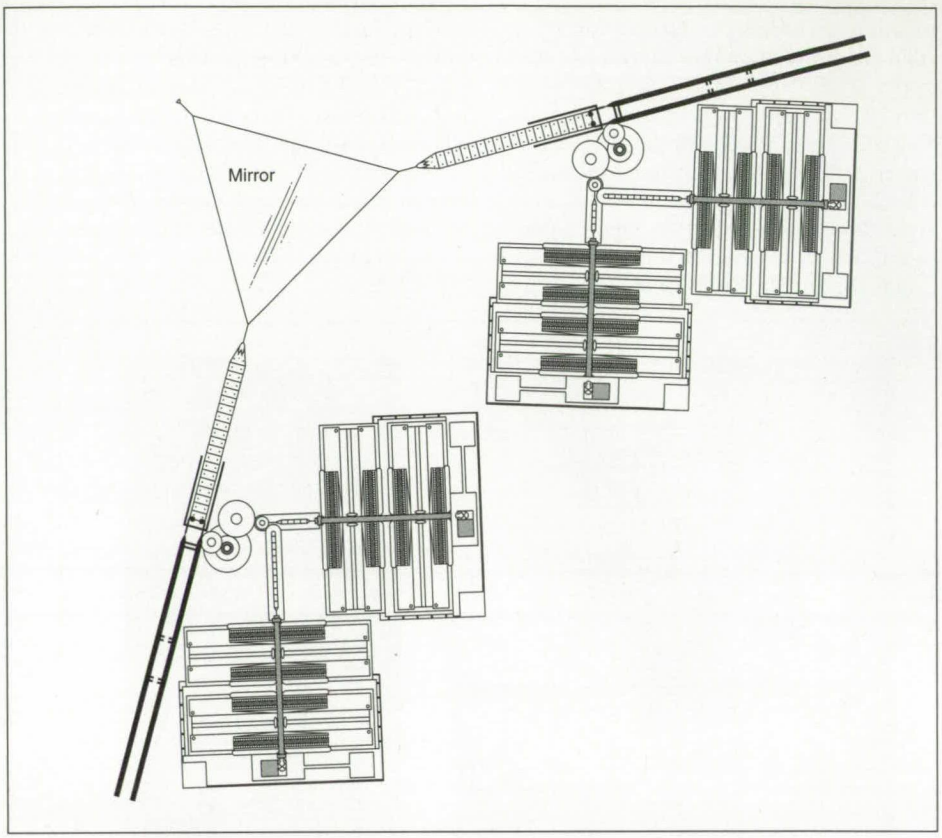
The triangular mirror would have sides 1.3 mm long. Translation of one corner of the mirror in a 0.415-μm increment as described above would result in a mirror rotation of ≈0.3 milliradian. The flexures would serve as smooth (free of stiction) means of bending and rotational coupling be-

tween the corners of the mirror and beams that hold the mirror on a substrate. The flexures could accommodate rotations and bends of at least half a radian. The maximum speed of translation, of a hinged beam would be 6 mm/s, corresponding to a rate of rotation of about a radian per second.

In principle, the mirror-aiming direction would be a known function of the number of phase steps from starting positions of the electrostatic comb drives. Inasmuch as the out-of-plane bending and torsion of the flexures would generate opposing forces on beams and all the way back to the pinion gears and comb drives, there would be no gear backlash and thus no need to account for backlash in calculating or controlling the mirror-aiming direction.

This work was done by Frank T. Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com /tsp*** *under the Machinery category.*

NPO-20971



The **Mirror Would Be Coupled** to micromachined steering mechanisms and supporting structures.

Making Three-Dimensional Holograms Visible From All Sides

Three-dimensional virtual reality displays could be viewed without visual aids.

NASA's Jet Propulsion Laboratory, Pasadena, California

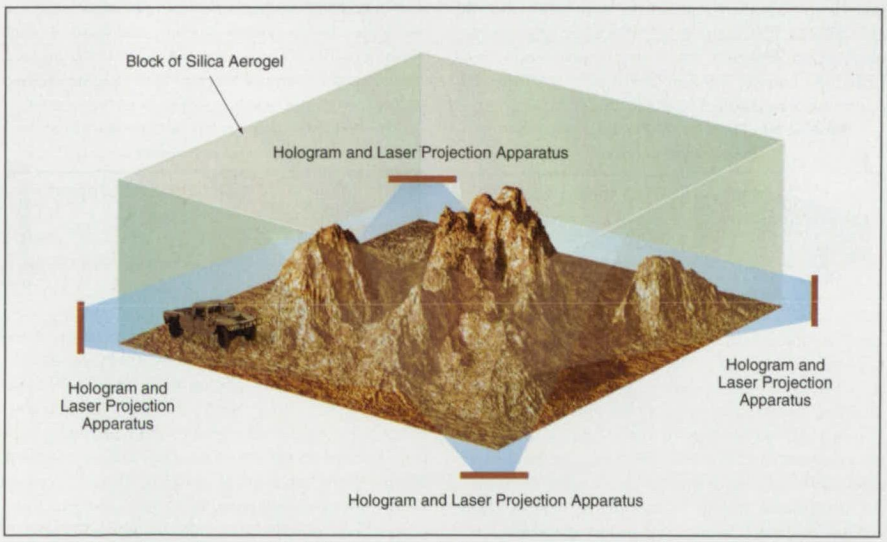
A technique for projecting holographic images to make both still and moving three-dimensional displays is undergoing development. Unlike older techniques based on stereoscopy to give the appearance of three-dimensionality, the developmental technique would not involve the use of polarizing goggles, goggles equipped with miniature video cameras, or other visual aids. Unlike in holographic display as practiced until now, visibility of the image would not be restricted to a narrow range of directions about a specified line of sight to a holographic projection plate. Instead, the image would be visible from any side or from the top; that is, from any position with a clear line of sight to the projection apparatus. In other words, the display could be viewed as though it were an ordinary three-dimensional object. The technique has obvious potential value for the entertainment industry, and for military uses like displaying battlefield scenes overlaid on three-dimensional terrain maps.

An essential element of the technique is the use of block of silica aerogel as the display medium. Silica aerogel is an open-cell glass foam with a chemical composition similar to that of quartz and a density as low as about one-tenth that of quartz. The sizes of cell features are of the order of 100 Å. Silica aerogel is a suitable display medium because it is nearly completely transparent, with just enough scattering and reflection to enable the generation of a real image.

The figure illustrates a conceptual application in which a three-dimensional topographical map would be displayed by fusing images projected into a block of silica aerogel from four separate holograms. One could use static holograms to project still images, either alone or in combination with computer-generated holograms to project moving or still images. A computer-generated hologram would be downloaded into a large liquid-crystal, which would be illuminated by a laser projection apparatus to display the holographic image in the aerogel block. For example, the terrain image could be projected from static holograms, while a computer-generated hologram would be used to depict a vehicle moving on the terrain.

This work was done by Frederick Mintz, Tien-Hsin Chao, Peter Tsou, and Nevin Bryant of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com/tsp*** *under the Physical Sciences category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL (818)354-2240. Refer to NPO-20101.



A **Three-Dimensional Topographical Map**, projected from holograms for display in a block of aerogel, would be visible from any position above the projection table. One of the holograms could be generated by a computer to depict a vehicle moving on the terrain.

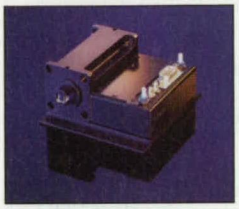
New Products

Product of the Month

Q-Switched CO_2 Laser

Coherent-DEOS, Coherent Photonics Group, Santa Clara, CA, has introduced the DIAMOND™ GEM Q-400 industrial Q-switched CO_2 laser that combines short, high-peak-power pulses with a rugged sealed package. The laser is designed for drilling and micromachining applications such as PCB microvia drilling, flex circuit machining, and plastics arocessing. It produces 15W average power at 50 kHz repetition rate, and 9.25 microns wavelength. The laser features 2.5 kW peak power with pulse widths controllable to less than 150 ns. Its RF-excited waveguide oscillator is sealed in an all-metal housing.

For Free Info Circle No. 734 or Enter No. 734 at www.nasatech.com/rs



Miniature Laser Modulators

LINOS Photonics, Milford, MA, offers miniature electro-optic modulators that allow full analog modulation of lasers with wavelengths in the range from 400 to 700 nm. A second device for the range of 300 to 400 nm also is available. The modular provides modulation frequencies up to 100 MHz, and the Gaussian beam profile of the laser is maintained by the electro-optic process. The unit is supplied as a complete system consisting of the electro-optic modulator, a driver unit, and the power supply.

For Free Info Circle No. 726 or Enter No. 726 at www.nasatech.com/rs

Analog Laser Sensor

Balluff, Florence, KY, offers the BOD-66M analog laser sensor for long-range measurement of parameters such as distance, height, and length in industrial applications. The sensor features 2m range, resolution of less than 5 mm, and analog and digital outputs for industrial automation. Applications include automated assembly, quality control, and dimensional measurement in packaging, material handling, automotive, and paper industries. The sensor uses laser triangulation to determine distance to objects. Target distance corresponds to the sensor's analog output voltage.

For Free Info Circle No. 729 or Enter No. 729 at www.nasatech.com/rs

Linear Light Source

The Opsis LightRanger™ light source from Wintriss Engineering Corp., San Diego, CA, is based on high-pressure sodium vapor lamp technology, and provides high-intensity light of 100,000 lux at four feet with a uniform 2" illumination line across an entire web. The light source enables hard-to-detect flaws to be visible to machine vision detection systems. Because of the wide light band produced, the system can neutralize the effect of web bounce. Optical feedback directly from the high-pressure sodium lamp to the 60-kHz lamp power supply provides stability of incident light throughout the estimated 40,000-hour lamp life.

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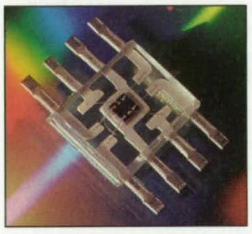

PIN Photodiodes

The S6795 and S7747 six-element silicon PIN photodiodes from Hamamatsu Corp., Bridgewater, NJ, are designed with clear plastic packages and operate over the 320 to 1000 nm spectral response range. They achieve peak sensitivity at 800 nm and have a response speed of 400 MHz. The S7747 can be used in violet laser detection applications, including optical disc pickup applications. The S6795 is suited for position detection, laser beam alignment, and CD, DVD, and MO disc signal readout.

For Free Info Circle No. 727 or Enter No. 727 at www.nasatech.com/rs

Fiber-Optic Amplifier

The 7087 fiber-optic amplifier from Automatic Timing & Controls, Lancaster, PA, features a backlit digital LCD display and provides an eight-step automatic gain control that enables fine adjustments. Other features include pushbutton auto-teach, adjustable threshold, NPN or PNP outputs at 100mA, programmable modulation selection for crosstalk protection, red LED light source, light-on/dark-on selectable, and operating temperature from -25° to 55°C.

For Free Info Circle No. 730 or Enter No. 730 at www.nasatech.com/rs

CCD Video Camera

Sony Electronics, Park Ridge, NJ, offers the XCD-SX900UV black and white digital CCD video camera with near-ultraviolet sensitivity. The camera captures images of minute surface details in applications such as semiconductor and fiber-optic inspection. It incorporates a 1/2-type Interline Transfer progressive scan CCD sensor based on Sony's HAD technology. It also features an SXGA video format of 1280 × 960. The camera measures 44 × 33 × 116 mm and is housed in a rugged enclosure for integration into machine vision systems. It is equipped with a C lens mount and has a flexible electronic shutter.

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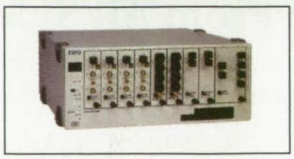


Optical Test System

The IQS-500 Intelligent Test System from EXFO, Vanier, Quebec, Canada, is a modular optical test system that can run up to 100 modules. The scalable system features a Pentium III, 866-MHz processor, 256 MB of memory, four PCI slots, a CD-ROM, and remote control via GPIB, RS-232, or Ethernet. It also features LabVIEW™ drivers, LabWINDOWS™ libraries, and Windows-based IQS Manager software for configuration and status visualization. The system is based on standard PC architecture, and features two USB ports, and external VGA, parallel, and serial ports.

For Free Info Circle No. 725 or Enter No. 725 at www.nasatech.com/rs

Imaging Spectrographs

The Optical Spectroscopy Division of Jobin Yvon Horiba, Edison, NJ, has introduced the TRIAX322 and TRIAX552 imaging spectrographs with dual array capabilities and 320 or 550 mm focal length. The axial exit port offers either resolution or imaging correction, while the lateral exit port is optimized for the best resolution correction. They can switch between two detectors without the need for re-alignment. Suited for CCD/InGaAs array combinations, the spectrographs feature triple-on-axis interchangeable grating turrets, full automation, direct digital scanning drive, and built-in dual RS-232/IEEE-488 interface.

For Free Info Circle No. 728 or Enter No. 728 at www.nasatech.com/rs

Color LED Measurement System

Gamma Scientific, San Diego, CA, has released the DR-2000 LED; a color LED measurement system that combines a radiometer/photometer with a photometric filter/detector. It performs photometric measurements of any color LED, and is designed for manufacturers of nearly any type of LED-based display. A built-in RS-232 interface allows users to control the system from a laptop or desktop computer. Control of all instrument functions is enabled through the computer interface, including manual and auto ranging modes, dark current suppression, and flux or energy modes.

For Free Info Circle No. 731 or Enter No. 731 at www.nasatech.com/rs

Diode-Pumped Laser

The Jasper™ diode-pumped Nd:YAG laser from New Wave Research, Fremont, CA, offers repetition rates from 100 Hz to 10 kHz with an output power greater than 2.5W at 10 kHz. Measuring 13.7" × 4.5" × 4.3", the unit features a control panel located on the power supply, providing control of all system variables. The laser can be triggered directly from the control panel or from a remote source through a rear-panel BNC. Most laser functions also can be controlled from a PC via an RS-232 port. A motorized optical attenuator provides energy control.

For Free Info Circle No. 735 or Enter No. 735 at www.nasatech.com/rs

Advanced Fatigue-Crack-Growth and Fracture-Mechanics Program

The NASGRO 3.0 computer program is an advanced version of a program used by NASA and the European Space Agency for fracture-control analysis of space-system structures and other hardware. The prior version, NASA/FLAGRO 2.0, was described in "Updated Fatigue-Crack-Growth and Fracture-Mechanics Software" (MSC-22550), *NASA Tech Briefs*, Vol. 19, No. 12 (December 1995), page 74. NASGRO 3.0 affords additional capability for durability and damage-tolerance analysis of aircraft structures and other mechanical systems. Because this code offers state-of-the-art and general capabilities in fracture mechanics and crack-propagation analysis, its usefulness extends beyond aerospace to numerous industrial applications: For example, it can provide guidance for prevention of catastrophic failures that originate in cracklike flaws in offshore oil structures, pressure vessels, pipes, diesel engines, and railroad tank cars. The program is also useful as an instructional device for courses in fatigue and fracture mechanics.

The objective in developing NASGRO 3.0 was to extend NASA/FLAGRO 2.0 (which was released in 1994) to accommodate more recent advancements in fracture mechanics and crack-propagation theory, to meet needs for damage-tolerance and durability analysis of aircraft, and to enable the program to function within the Windows 95/98, Windows NT, and Unix operating systems. The changes made in pursuit of this objective were the following:

- A graphical user interface (GUI) was developed to make input of data easier and more intuitive.
- Load-interactive or retardation routines were added to account for changes in crack-growth rates due to fatigue spectrum (nonconstant) loading. Five different mathematical models have been included: the generalized Willenborg, the modified generalized Willenborg, the Walker-Chang-Willenborg, the strip-yield, and the constant-closure models.
- New and improved crack solutions were added for cases of bolts, cracks from holes, and nonlinear stress distributions.
- Spectrum-input routines have been improved to provide more flexibility in the use of pre-existing spectrum files.
- A materials database has been added, along with a GUI that gives users access to the data from which the material-property curves are derived. A software module called "NASMAT" contains a base of experimental data that are available for easy access, viewing, and use in deriving crack-growth material constants required for safe-life analysis.
- The threshold equation has been improved by incorporation of a newer, more accurate mathematical model of fatigue-crack-growth thresholds.

This program was written by Royce G. Forman of **Johnson Space Center**; *V. Shivakumar, Sambi Mettu, Joachim Beek, and Feng Yeh of Lockheed Martin; and Leonard Williams of GB Tech, Inc., and is available at http://mmptdpublic.jsc.nasa.gov/nasgro/nasgromain.html.*
MSC-23082

Software for Sequencing Spacecraft Actions

SEQ_GEN is a component of the Sequence Subsystem computer program, which assists in generating a sequence of commands to be executed by a control computer aboard a spacecraft to perform scientific observations and supporting engineering actions in response to requests by numerous users. SEQ_GEN assists a designer in devising a final, valid sequence. Using SEQ_GEN, the designer prepares a file of requested spacecraft actions. SEQ_GEN then processes this file plus a file of spacecraft- and mission-specific information prepared by another Sequence Subsystem software component to (1) generate the sequence of commands, (2) predict what the commands will cause to happen on the spacecraft, and (3) give warnings when the sequence violates rules or causes misuse of spacecraft systems. SEQ_GEN generates an interactive graphical time-line display of the predictions and warnings. The user can change the sequence by keyboard entry in a text file, or by use of a mouse to add or delete an item or move an item to a new position on the display. SEQ_GEN then processes the revised input data, starting from a time earlier than the earliest time affected by the change(s). The process is repeated, if necessary, until a valid sequence is produced.

This program was written by Russell M. Brill, Dang Le, Imin Lin, Winthrop Lombard II, Robert Oliphant, Taifun O'Reilly, Jose J. Salcedo, and Thomas W. Starbird of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20452.

Program Distributes and Tracks Organizational Memoranda

Closed Loop Accounting Management System (CLAMS) is a computer program for Web-based distribution and tracking of memoranda within an organization. An item for distribution is entered by a user who has administrative access. The item is assigned to affected users, to whom e-mail messages are sent. Upon receipt of such an e-mail message, a user gains access to an "open items" page from a link within the message. From the "open items" page, the user can (1) link to the item, (2) select a "notes" button to leave a reminder about the item, or (3) select a "close" button to close the item, indicating that the user has received and understands the item. CLAMS can be used to effect the automated distribution of new and updated items to users on predetermined lists. CLAMS enables managers to track the statuses of users and distributed items: For a given item, CLAMS can tell (1) who has it open and for how long and (2) who closed it and when; regarding a given user, CLAMS can tell (1) which items the user has open and for how long and (2) which items the user closed and when.

This program was written by Mike Olejarski of United Space Alliance for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*

KSC-12289

Flat Membrane Device for Dehumidification of Air

Water vapor is not condensed; instead, it is transported to vacuum.

Lyndon B. Johnson Space Center, Houston, Texas

A device based on the transport of water through a membrane to a vacuum has been developed for dehumidifying a stream of air in the life-support system of a spacecraft or space suit. The device could also be adapted to terrestrial use in dehumidification of air in an air-conditioning stream or drying of air or another gas in a chemical processing stream. The design of this device is an advance in that it decreases (relative to prior designs) the weight, power consumption, and volume of the dehumidifier in the life-support system or other gas-circulation system in which the device is used. In the case of a spacecraft or space suit, the design thereby also increases safety and health margins. Although the membranes in the device must be replaced periodically and a vacuum source is essential for its operation, no other dehumidifier works as well in a spacecraft or space suit.

Unless controlled, the concentrations of CO_2 and H_2O in respirable air in a spacecraft or space suit quickly reach unacceptably high levels. Heretofore, life-support systems in spacecraft and space suits have included solid metal hydroxides for depleting exhaled CO_2, and condensers integrated with cooling sources for removing excess moisture. To enable the condensers to function, such systems must also include microgravitational phase separators and coolant/heat sink subsystems, all of which contribute to weight, volume, and consumption of power.

The present device operates without need for either a coolant/heat sink subsystem or a microgravitational phase separator. Moreover, in the original outer space application, the vacuum needed for operation is available naturally, so that it is not necessary to incur the cost, weight, and power penalty of a vacuum source. Hence, in comparison with breathing air systems of prior design, it is possible to simplify breathing loop interfaces, reduce weight and volume, and decrease the amount of power expended, thereby also saving on the cost of fuel.

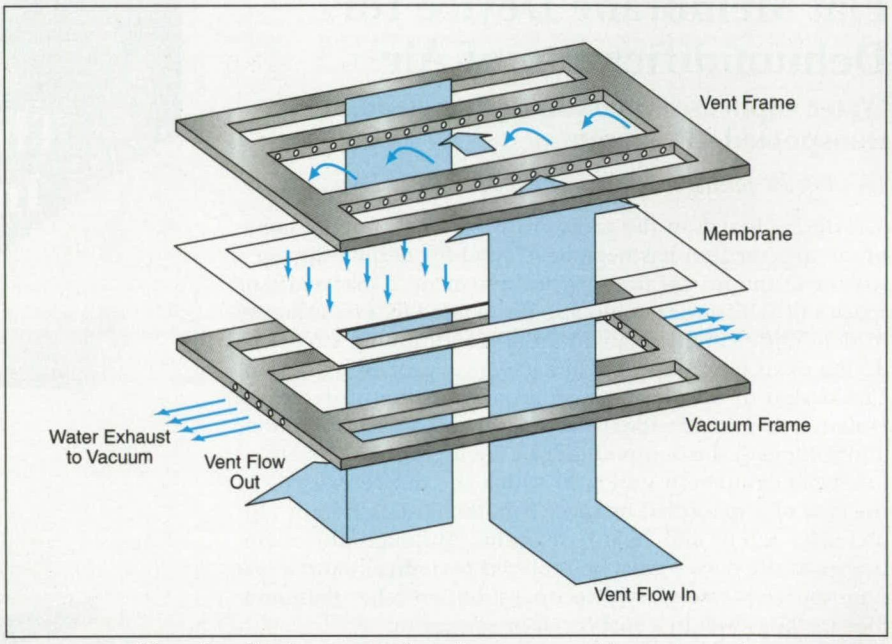
The device contains one or more modules in which spaces in a vent-layer assembly alternate with spaces in a vacuum-layer assembly and the vent and vacuum spaces are separated by flat sheets of a polyelectric membrane material that is permeable by water (see figure). The vent-layer assembly includes a vent frame, a metal foam insert, and screens. The frame is rectangular and is sized to optimize the pressure drop characteristics of the vent-gas and water-vapor flows. The metal foam insert is bonded to the top and bottom of the frame and sandwiched between a pair of screens that provide additional support so that the membrane is not torn against the surface of the metal foam. Flow holes connect the central section of the frame to header slots and allow humid gas to enter the frame without leaking into the vacuum space. Dovetailed O rings grooved to fit the perimeter of the frame retain a gasket during assembly of the module. The

thickness of the vent layer is chosen to be the minimum thickness needed to maintain top and bottom gasket seals.

The vacuum-layer assembly is similar to the vent-layer assembly except that its flow holes are on the short ends and there is no header for a vacuum-layer, eliminating the need for another set of gaskets on each layer. Inasmuch as the flow of water vapor is a fraction (typically 4 percent by volume) of the flow of the gas to be dehumidified (hereafter called vent gas for short), the vacuum frame can be made thinner than the vent frame to minimize overall volume. This frame is so thin that a single gasket, held in place by a retaining ring, seals against layers above and below the vent layers. The number and size of vacuum holes satisfy two constraints: (1) the minimum equivalent area limits the back pressure of vapor; and (2) the maximum equivalent area restricts the vent flow if one or more membranes rupture. Top and bottom end plates, sized to provide sufficient stiffness, apply an even pressure to the gaskets to prevent leakage. These plates also include ports through which the vent gas flows into and out of the module, plus ports for testing the vent gas.

Modules like the one described above are stacked in alternating layers, beginning and ending with a vacuum frame. The modular nature of the device provides flexibility for changing the membrane area to satisfying requirements for the conditions of a particular application.

This work was done by Karen Murdoch and C. H. Miller of United Technologies for **Johnson Space Center**. *For further information, contact the Johnson Commercial Technology Office at 281-483-3809 or commercialization@jsc.nasa.gov*
MSC-22878



Water Vapor Diffuses from flowing vent gas through water permeable membranes into a vacuum.

Inverted Hindle Mount Reduces Sag of a Large, Precise Mirror

The mirror is suspended from above by multiple, equally loaded supports.

Goddard Space Flight Center, Greenbelt, Maryland

A mount has been devised to satisfy a requirement to suspend a highly precise, flat, circular, low-thermal-expansion glass mirror in a horizontal plane with its reflective side down while keeping the reflective mirror surface flat to within a peak-to-valley depth of less 50 nm. The difficulty of the suspension problem and the significance of the mount conceived as the solution of the problem arise from the large size and weight of the mirror (diameter 101.7 cm, thickness 18.8 cm, mass 385 kg).

The mount is an inverted version of the Hindle mount, which was first published in 1945 and is named after its inventor (Dr. J. H. Hindle). The Hindle mount supports a flat, circular mirror on multiple pads that are located so that all of the pads bear the same proportion of the total weight and the sag of the mirror under its own weight between the supports is minimized. The number of support pads in a Hindle mount is an integer multiple of three. The sag can be reduced by increasing the number of support pads. The present mount is based on a Hindle-mount geometry of nine support points grouped into three triangles (see Figure 1).

The original Hindle-mount concept applies to a mirror suspended from its lower face with its reflective side up; the weight of the mirror presses it against the support pads, and the resulting friction often suffices to hold the mirror in place on the pads. In the present inverted Hindle mount, the mirror is suspended

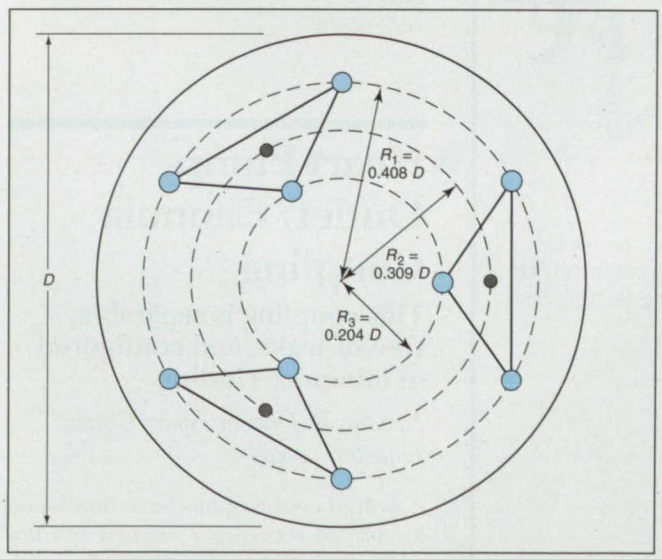


Figure 1. The **Nine-Point Hindle Mount** includes six supports on a circle with a radius of 0.408*D* and three supports on a circle with a radius of 0.204*D*, where *D* is the outer diameter of the mirror. The supports in each group of three are connected to a triangular plate supported at its centroid, which lies on a circle with radius 0.309*D*. When the three triangular plates are picked up at their centroids, equal weight is borne by all nine supports.

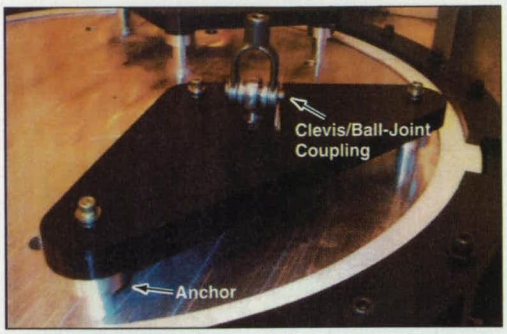


Figure 2. **Parts of the Inverted Hindle Mount** are attached to an aluminum disk of the same size as (and slightly heavier than) the glass mirror that the mount is intended to support. (The aluminum disk was used during development so as not to risk damage to the expensive glass mirror.)

from its upper face; consequently, the weight of the mirror tends to pull it away from its supports, making it necessary to fasten the mirror to the supports in some fashion.

Figure 2 depicts some parts of the present inverted Hindle mount. The nine supports are made of Invar — a low-thermal-expansion Fe/Ni alloy. To distinguish them from the compression-loaded support pads of a traditional Hindle mount, these tensile-loaded supports are called "anchors." The lower end of each anchor has an area of 3 in.^{2} (≈19.4 cm^2) and is bonded to the face of the mirror by use of 3M's 2216 (or equivalent) clear high-performance epoxy. The upper end of each anchor is tapped to accept a bolt. The upper ends of the anchors in each group of three are bolted loosely, with spherical washers, to a triangular aluminum plate 1 in. (2.54 cm) thick. The loose bolting and spherical washers allow some limited rotation and translation, thereby helping to prevent the buildup of bending moments that could cause the anchors to peel away from the mirror surface at the epoxy joints.

Each plate is supported from above by means of a clevis/ball-joint coupling attached to the plate at the centroid of the triangle defined by the three support points. The clevis is, in turn, supported from above by a threaded rod that passes through a massive overhead frame and engages a nut on top of the frame. The freedom of rotation of the clevis/ball joints contributes to the relief of any bending moments that could, if allowed to build up, cause peeling at the epoxy joints.

Experience in the development of the inverted Hindle mount revealed that it can be difficult to form reliable epoxy bonds between the anchors and the top surface of the mirror. Therefore, the mount must be augmented by handling fixtures with safety features to prevent the mirror from falling in the event of failure of one or more epoxy bonds.

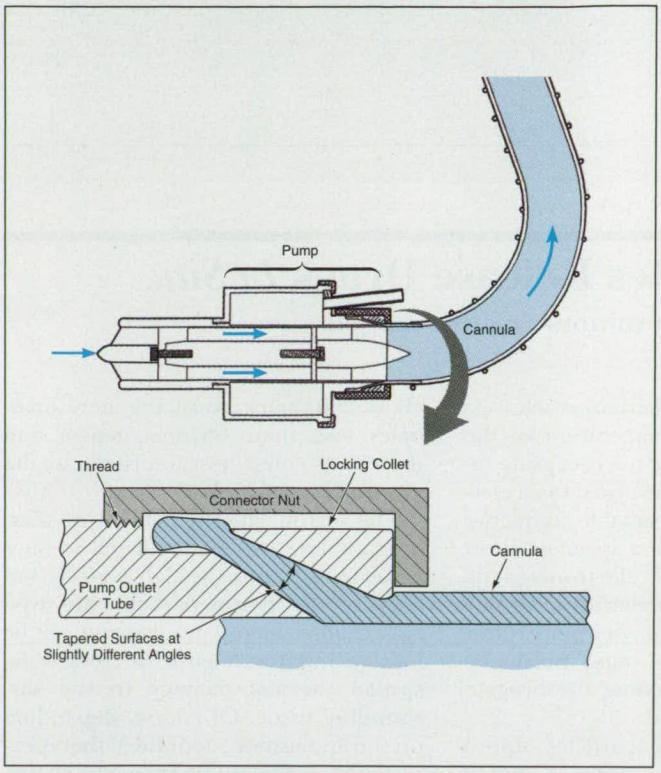
This work was done by David W. Robinson of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*
GSC-14316

Heart-Pump-Outlet/Cannula Coupling

This coupling is separable, free of leaks, and configured to minimize clotting.

Lyndon B. Johnson Space Center, Houston, Texas

A fluid coupling has been developed for use in securing a vascular outflow graft (cannula) to the outlet of a surgically implanted NASA/DeBakey heart-assist pump. The design of the coupling can also be adapted to other applications in which it is necessary to



This **Heart-Pump-Outlet/Cannula Coupling** is superior to other couplings (e.g., simple hose-clamp couplings) that were not designed for coupling heart pumps.

join flexible tubes with rigid ones. A joint formed by use of this coupling is separable, yet free of leaks; this is advantageous in that (1) it is necessary to be able to install or remove a pump in accordance with requirements for surgery, sterilization, and pump maintenance, but (2) seepage of blood from an installed pump/cannula joint cannot be tolerated. Moreover, the coupling provides a smooth transition for flow from the pump outlet to the cannula; this feature helps to prevent clotting, which is triggered by flow-surface discontinuities.

The coupling (see figure) includes tapered and threaded surfaces on the pump outlet tube, a differentially tapered locking collet, a connector nut that mates with the thread on the pump outlet tube, and the affected end portion of the cannula. A volume is provided at the upstream end of the tapered outlet-tube surface to allow excess cannula material (including material extruded by the clamping described below) to expand to form a bulbous collar that helps to retain the cannula in place. This volume also facilitates manufacture and assembly, inasmuch as it desensitizes the joint to slight variations in cannula geometry.

The differential angle between the tapered surfaces of the pump outlet and the locking collet helps to clamp the cannula in place and to provide a seal when the connector nut is tightened. The radial clearance between the locking collet and the connector nut is sufficient to allow the collet to move slightly to align itself for uniform clamping of the cannula. The nut can be tightened to obtain the desired clamping and sealing force, or can be loosened to disconnect the pump from the cannula.

This work was done by Bernard J. Rosenbaum of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

This invention has been patented by NASA (U.S. Patent No. 6,050,987). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to MSC-22865.

Externally Triggered Microcapsules Release Drugs *In Situ*

Drugs can be released, at designated times, within tumors or other targets.

Lyndon B. Johnson Space Center, Houston, Texas

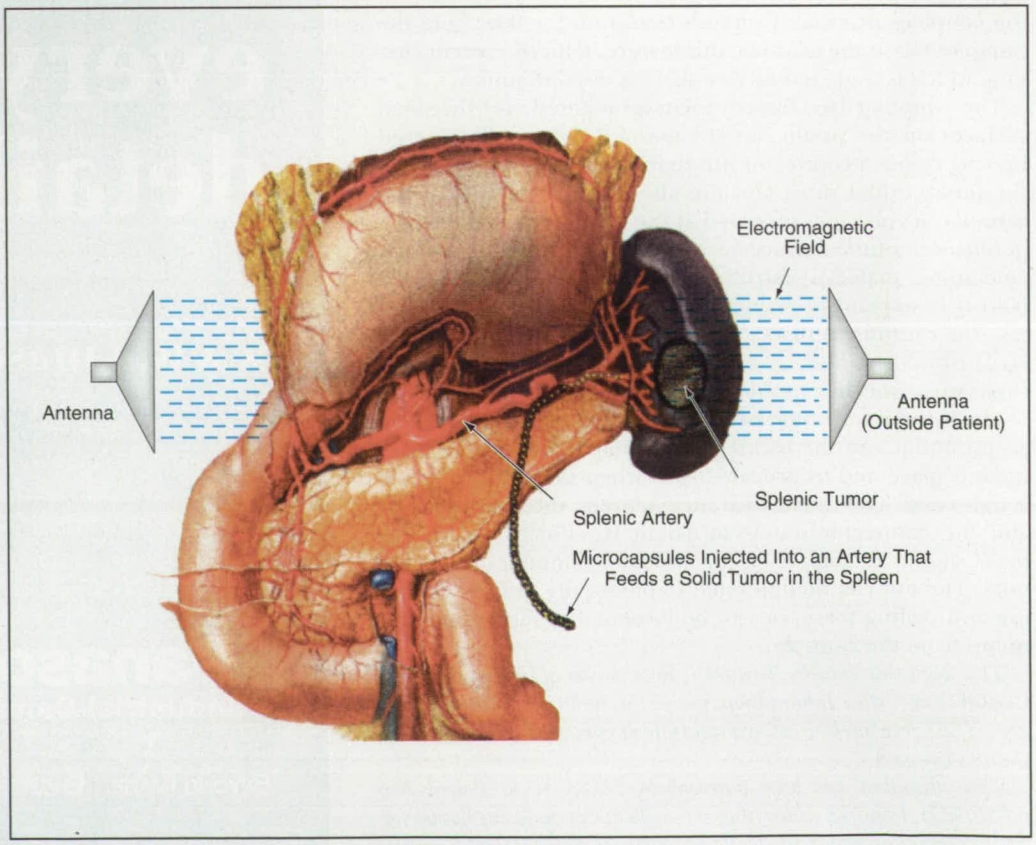
In an advanced method of administering drugs to target sites in human bodies, the drugs in liquid form are contained in microcapsules that are injected, and then, by exposing the target sites to externally generated electromagnetic fields, the microcapsules are lysed to release the drugs. Such externally triggered microcapsules are intended primarily for use in combined-modality therapies of cancer. In a given application, the external electromagnetic field can be applied to cause the release of the encapsulated drug(s) at a prescribed time or when the microcapsules are confirmed to be located in a specific tissue.

The concept of microencapsulation of drugs was reported in "Microencapsulation of Multiple Drugs" (MSC-22489), *NASA Tech Briefs*, Vol. 20, No. 11 (November 1996), page 92. More recently, an external-triggering method related to the present method was reported in "*In Situ* Activation of Microencapsulated Drugs (MSC-22866)," *NASA Tech Briefs*, Vol. 24, No. 9 (September 2000), page 64. A microcapsule of the type used in the present method is a multilayer structure that contains a concentrated drug solution. The outer layer of the microcapsule is a polymeric membrane that is both transparent to electromagnetic radiation and insoluble in aqueous fluids. Also contained within the microcapsule, in a compartment next to the outer membrane, is a fluid-filled compartment that contains one or more ferromagnetic thermoparticles.

The microcapsules are designed to be injected into arteries that lead to vascularized tumors or other target tissues (see figure). The outer-membrane polymer and the thermoparticle material are chosen so that the Curie temperature of the thermoparticles exceeds the melting temperature of the polymer. When the microcapsule-infused target region is exposed to an electromagnetic field of suitable frequency and power density for a specified short time (minutes), the electromagnetic field heats the thermoparticles. The localized heating of the thermoparticles melts a hole in the outer polymeric membrane, thus releasing the drug to the surrounding tissue.

Because the thermoparticles absorb the electromagnetic radiation much more strongly than do the surrounding microcapsule materials and tissues, an electromagnetic field of relatively low power can be used to effect drug release. Regulating the exposure to the electromagnetic field is not a major problem: Heating is automatically limited to the Curie temperature because above that temperature, the thermoparticles lose their ferromagnetism and thereby become less absorbent to the electromagnetic field.

The ferromagnetic material of thermoparticles can be formulated to have Curie temperatures as high as 80 °C, but because the thermoparticles are typically smaller than 1 μm, heating can be localized well enough to prevent widespread thermal damage to the surrounding tissue. Of course, depending on the application, additional therapeutic advantage might be gained by changing the frequency and/or power of the electromagnetic field, after the microcapsules have been lysed, to obtain controlled hyperthermia to enhance the local effectiveness of the drugs that have been released. In some applications, it could be desirable to effect multiple releases of the same drug or different



Microcapsules Containing One or More Drug(s) are injected into an artery that feeds a tumor — in this case, in the spleen. The capsules are then lysed by applying an electromagnetic field.

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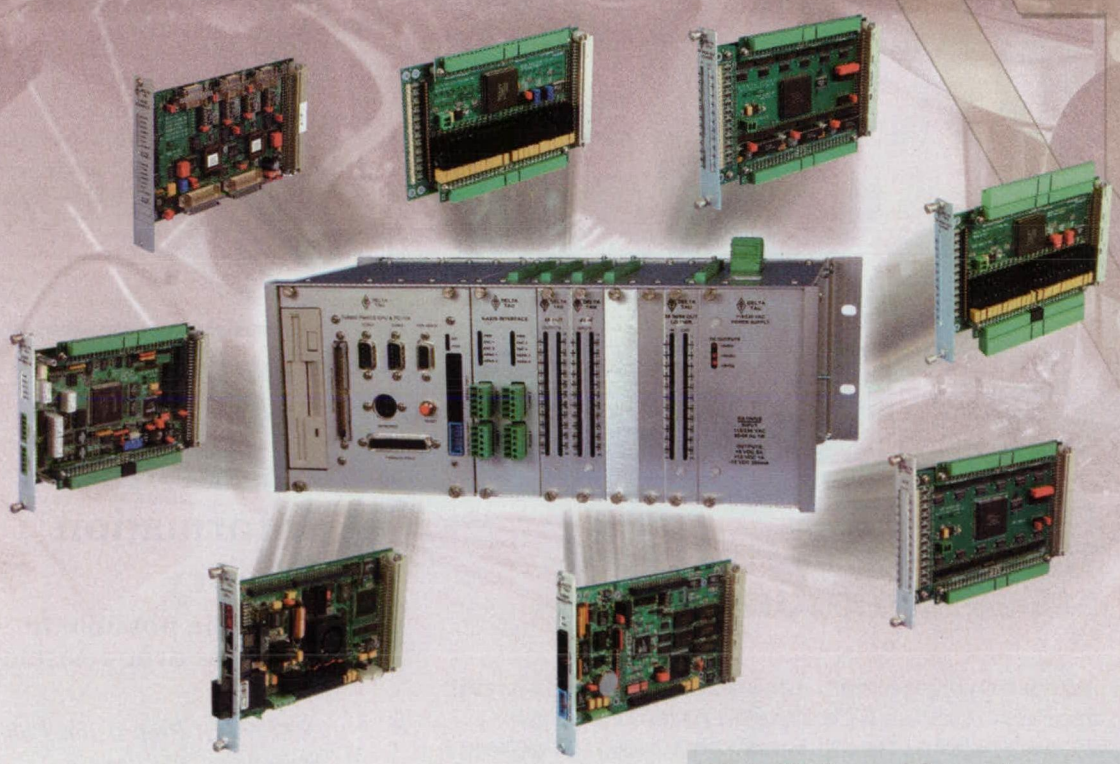

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drugs by use of injecting mixtures of microcapsules containing ferromagnetic particles with different Curie temperatures that could be triggered at different times, as determined by the strength of the electromagnetic field and the duration of exposure.

This work was done by Dennis R. Morrison and Benjamin Mosier of **Johnson Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Bio-Medical category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22939.

Combinatorial Drug Design Augmented by Information Theory

It may be possible to suppress drug-resistant viruses.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method of designing antiviral drugs provides for the utilization of combinatorial-chemistry techniques that have been used previously for this purpose, in conjunction with applicable principles of information theory. In its information-theoretic aspect, the method can be characterized as one of maximizing the mutual information between (1) ensembles of drugs and (2) ensembles of viruses that one seeks to combat by use of the drugs (denoted in the art as targets). The method would entail increases in the time and cost of development of drugs, but these disadvantages could be offset by reduction or prevention of the emergence of drug-resistant viral populations.

Heretofore, it has been standard practice to design an antiviral drug to bind to a "consensus-sequence" protein of a viral species or target ensemble. However, consensus-sequence proteins are conceptual only; they do not occur in nature. In treatment-naïve patients (that is, patients who have not taken

the drug), many viral targets are polymorphic, such that the drug is not specific to many of the mutants in the target population. As a consequence, the drug-resistant mutants quickly become the dominant species in the viral population; in other words, the viral targets become drug-resistant.

The proposed method is based partly on recognition that the ensemble of proteins of a viral target forms a "quasispecies" of mutants characterized by a particular entropic profile. Hence, one should have a greater chance of suppressing the rise of drug-resistant mutants through combinatorial design of a drug to combat the quasispecies, rather than the consensus-sequence species. One would seek a drug that binds not only to the consensus target but also to its mutants. Depending on the viral target, the most effective drug might, itself, be a quasispecies in that it would be an ensemble of drugs.

An ensemble of drugs with substitution probabilities complementary to those of the entropic profile of the target could be even more effective. Such an ensemble of drugs could be designed in a procedure that minimizes the conditional target entropy. In such a procedure, combinatorial ensembles of drugs would be used on mixtures of targets prepared according to the treatment-naïve substitution probabilities. In a sequence of "passes," the target ensemble would be treated with a drug ensemble and then resequenced to measure the remaining entropy of the target ensemble, given the drug ensemble. By use of a suitable algorithm, the combinatorial drug ensemble could then be modified in further steps until the conditional target entropy was minimal, at which point the drug ensemble could be considered optimal.

This work was done by Christoph Adami of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Bio-Medical category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Intellectual Property group
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240
E-mail: ipgroup@jpl.nasa.gov

Refer to NPO-30252, volume and number of this NASA Tech Briefs *issue, and the page number.*

Multiple-Path-Length Optical Absorbance Cell

Wide dynamic range is provided for measuring widely different concentrations of CDOM.

Stennis Space Center, Mississippi

An optical absorbance cell that offers a selection of multiple optical path lengths has been developed as part of a portable spectrometric instrument that measures absorption spectra of small samples of water and that costs less than does a conventional, non-portable laboratory spectrometer. The instrument is intended, more specifically, for use in studying colored dissolved organic matter (CDOM) in seawater, especially in coastal regions. Accurate characterization of CDOM is necessary for building bio-optical mathematical models of seawater. The multiple path lengths of the absorption cell afford a wide range of sensitivity needed for measuring the optical absorbances associated with the wide range of concentrations of CDOM observed in nature.

The instrument operates in the wavelength range of 370 to 725 nm. The major subsystems of the instrument (see figure) include a color-balanced light source; the absorption cell; a peristaltic pump; a high-precision, low-noise fiber-optic spectrometer; and a laptop or other personal computer. A fiber-optic cable transmits light from the source to the absorption cell. Other optical fibers transmit light from the absorption cell to the spectrometer, as described below.

The absorption cell is of a type known in the art as a liquid-core waveguide: the liquid to be characterized is contained in a narrow tube. The material of the tube or a material coating the outside of the tube is chosen to be of an index of refraction less than that of the liquid so that light propagating inside the liquid remains confined by total internal reflection. Thus, the liquid and tube constitute an optical waveguide or optical fiber.

The tube has an inner diameter of 2 mm and is coiled for compactness. The peristaltic pump draws the sample water from a beaker into and along the tube and discharges the water into another beaker. Light that has propagated through the liquid in the tube is collected by an optical fiber at path lengths of 2, 10, 50, and 200 cm from

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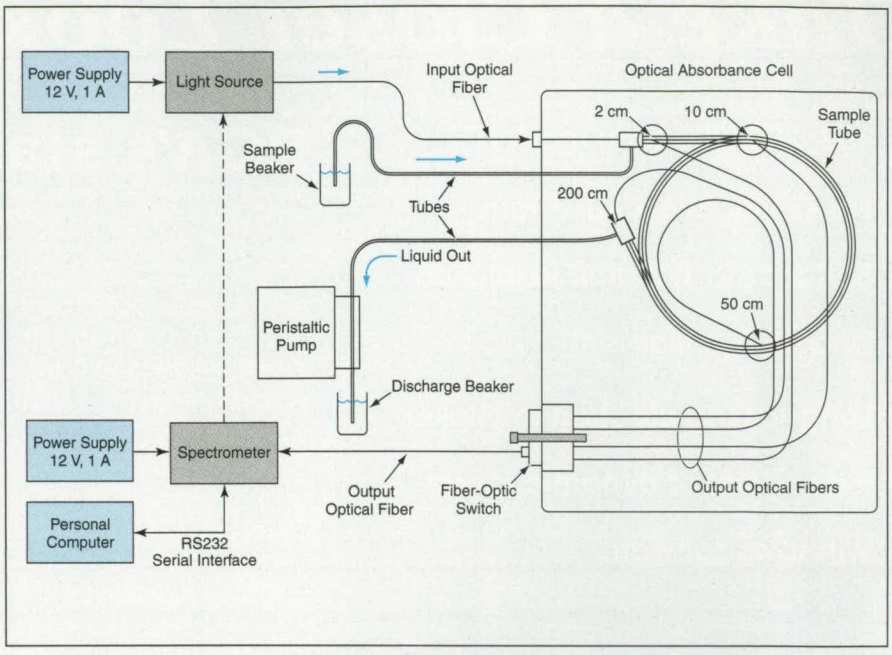

The **Optical Absorbance Cell** of this instrument is a liquid-core waveguide that includes fiber-optic taps for measuring absorption over several different path lengths.

the light-input end. By means of a fiber-optic switch, the light from one of these optical path lengths is selected for transmission to the spectrometer via a fiber-optic cable. The spectrometer readings are transmitted to the computer for analysis.

In tests using phenol red secondary standards, the instrument exhibited a baseline repeatability in absorbance of better than 1 mAU. During absorption measurements of natural CDOM samples, the instrument exhibited a sensitivity of about 0.002 m^{-1} at a wavelength of 370 nm. On the other hand, it was found that by using the 2-cm path length cell, one could measure CDOM absorbance as high as 200 m^{-1} at 370 nm. Hence, the instrument has an exceptional dynamic range, as needed to measure a wide range of CDOM concentrations.

This work was done by Richard L. Miller of **Stennis Space Center** *and Mathias Belz and Su Yi Liu of World Precision Instruments Inc.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

World Precision Instruments Inc.
175 Sarasota Center Boulevard
Sarasota, FL 34240

Refer to SSC-00143, volume and number of this NASA Tech Briefs *issue, and the page number.*

Model of a Fluidized Bed Containing a Mixture of Particles

Predictions thus far are in reasonable agreement with experimental data.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mathematical model has been developed for use in analyzing the dynamics of an isothermal, non-chemically-reacting mixture of particles in a bubbling fluidized bed. Although the model has generic validity, it is intended, more specifically, to be applied to a fluidized bed that contains a mixture of sand and biomass particles, fluidized by steam. The model includes components in common with the models described in "Model of Pyrolysis of Biomass in a Fluidized-Bed Reactor" (NPO-20708), *NASA Tech Briefs*, Vol. 25, No. 6 (June 2001), page 59 and "Multiphase-Flow Model of Fluidized-Bed Pyrolysis of Biomass" (NPO-20789), *NASA Tech Briefs*, Vol. 26, No. 2 (February 2002), page 56.

The derivation of the model follows a multifluid approach according to which macroscopic transport equations

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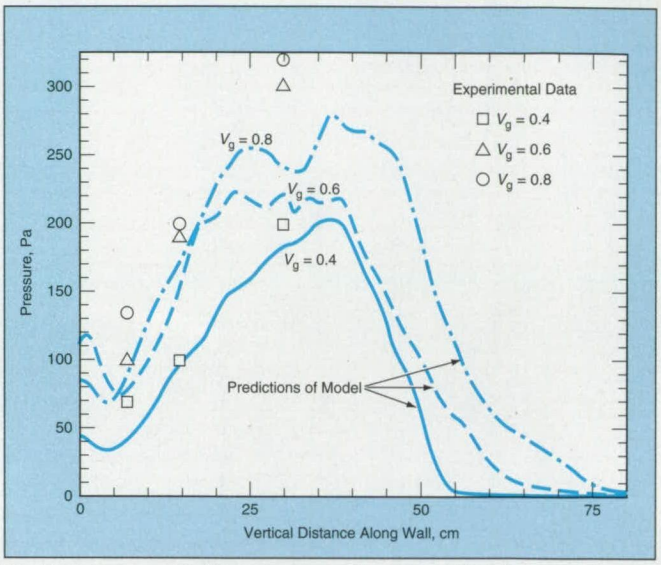


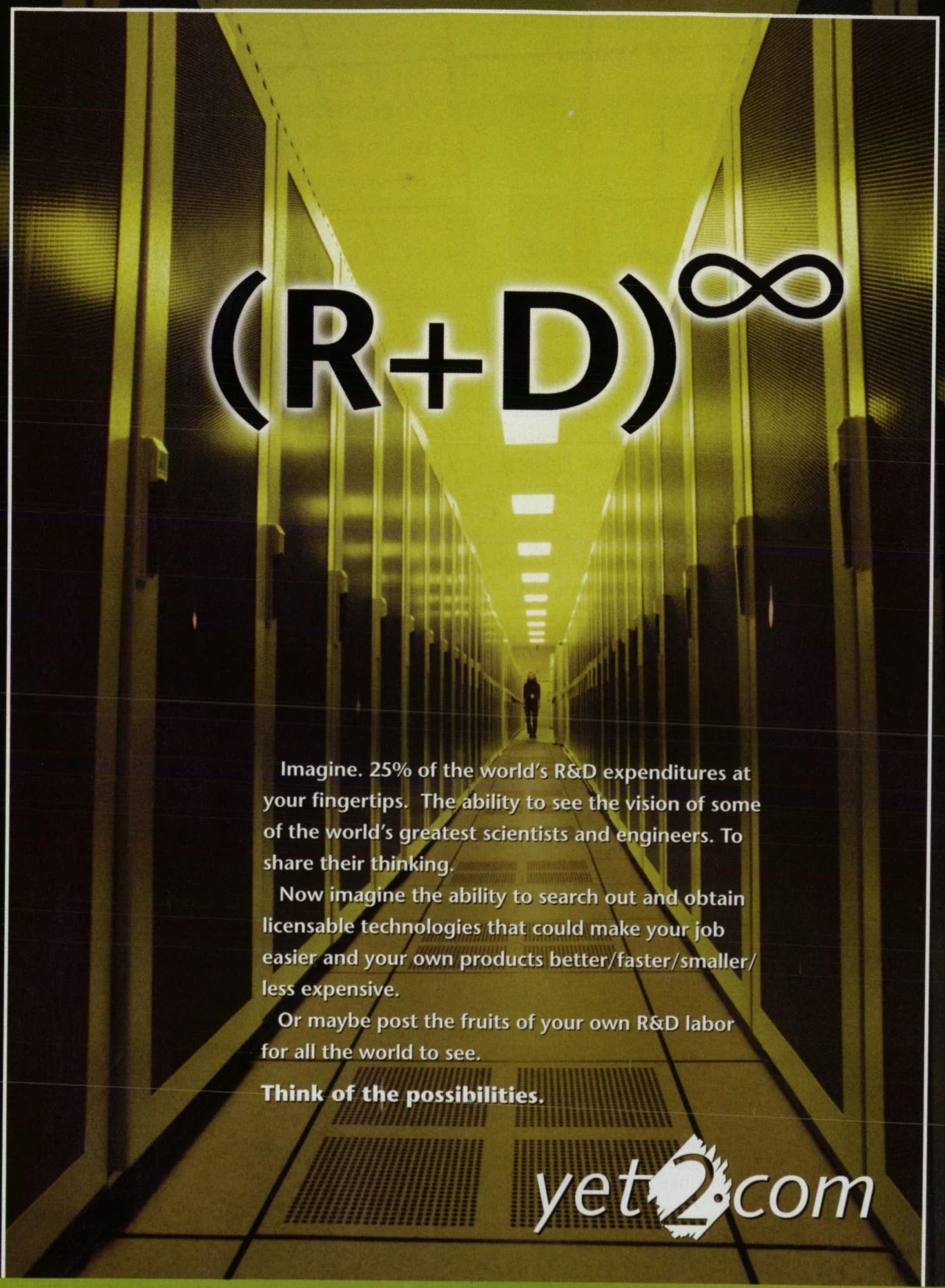
The **Time-Averaged Solids Pressure** as a function of height along the wall of a bed of glass beads fluidized with air was computed by the model and measured at superficial gas speeds of 0.4, 0.6, and 0.8 m/s. (The beads had a diameter of 0.5 mm and a density of 2.5 g/cm^3, the channel had a square cross section 12.7 × 12.7 cm, and the bed was initially filled with beads to a depth of 43 cm.)

are derived by taking suitable ensemble averages of the equations for the local dynamics of the gas and particle phases. A standard phasic ensemble average is selected for the gas phase. For the particles, transport equations for each particle species (e.g., a set of equations for sand and another for biomass) are derived, starting with concepts from kinetic theory. An important difference from classical kinetic theory occurs because inelasticity of collisions between macroscopic particles and the consequent dissipation of energy must be represented by appropriate models. Furthermore, the interstitial gas exerts drag on the particles, leading to interaction terms in the averaged transport equations. One especially notable component of the theory is the concept of granular temperature, which represents the mean kinetic energy associated with fluctuations in the velocities of the particles.

The resulting model equations describe the dynamics in terms of the conservation of mass, momentum, and granular temperature for each species of particles. These equations can describe the independent accelerations of, and the exchanges of momentum and energy among, the particle species. The equations for the particle species are closed by providing a separate Gaussian distribution of velocity for each particle species; this provision is valid as long as gradients of the mean variables are small and the particles behave approximately as nearly elastic hard spheres. In the regions of very high solids volume fractions, the stress tensor is augmented by a frictional-transfer submodel of stress vs. strain.

The model has been applied in several test cases: (1) predictions of the shear and normal stresses in homogeneous shear flows, (2) simulations of the particle pressure along the wall of a bubbling bed, and (3) a comparison between simulations of monodisperse and binary mixtures in a homogeneously aerated bed. For cases for which experimental data were available, the results of the simulations were found to approximate the data reasonably well (for example, see figure).

This work was done by Josette Bellan and Danny Lathouwers of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*
NPO-20937



Refractive Secondary Concentrators for Solar Thermal Systems

Concentration ratios as high as 10^4 and operating temperatures >2,000 K are anticipated.

John H. Glenn Research Center, Cleveland, Ohio

High-throughput, non-imaging, secondary concentrating optics that utilize refraction and total internal reflection are undergoing development for use in conjunction with advanced primary solar concentrators to provide solar thermal energy for space applications. This development is prompted by (1) a need to concentrate sunlight by factors of as much as 10^4 to satisfy design and operating requirements for some advanced solar thermal systems and (2) the impracticality of fabricating primary concentrators with sufficient precision to afford such high concentration ratios by themselves. Figure 1 illustrates the operation of a refractive secondary concentrator.

The innovative refractive secondary concentrator offers significant advantages over all other types of secondary concentrators. The refractive secondary offers the highest throughput efficiency, provides for flux tailoring, requires no active cooling, relaxes the pointing and tracking requirements of the primary concentrator, and enables very high system concentration ratios. This technology has broad applicability to any system that requires the conversion of solar energy to heat, including electric power generation, thermal propulsion and high temperature furnaces. NASA Glenn initiated the development of the refractive secondary concentrator in support of Shooting Star, a solar thermal propulsion flight experiment, and continued the development in support of Space Solar Power.

A prototype sapphire refractive secondary concentrator (see Figure 2), has completed solar vacuum performance testing using a liquid-cooled calorimeter in NASA Glenn's Tank 6 facility. The effort involved the design and fabrication of a sapphire refractive secondary concentrator, design and fabrication of a calorimeter and its support systems, calibration of the calorimeter, on-sun vacuum testing of the refractive secondary, and comparing the test results with modeling predictions.

The prototype refractive secondary concentrator, measuring 3.5 in. (8.9 cm) in diameter and 11.2 in. (28.5 cm) long, was designed for the Tank 6 facility and the existing primary concentrator/solar simulator system. Ray trace optics software was used to model the secondary concentrator resulting in predicted efficiency without an antireflective coating of 90 percent. The solar vacuum test results indicate an average throughput effi-

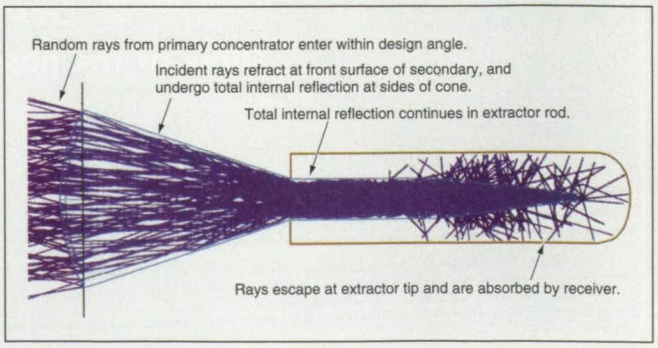


Figure 1. A **Reflective Secondary Concentrator** efficiently concentrates solar energy from a primary concentrator then allows the energy to escape onto a receiver cavity.

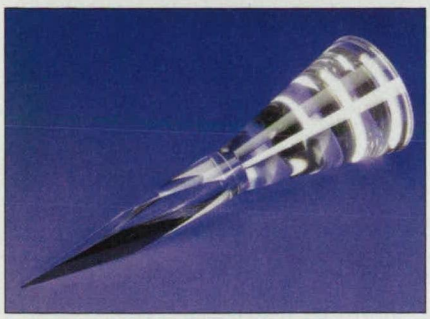


Figure 2. A **Prototype Sapphire Refractive Secondary Concentrator** is shown.

ciency of 87 percent, which agrees well with the modeling predictions. It is anticipated that reduction of a known reflection loss off of the inlet surface by applying an antireflective coating to that surface would result in a secondary concentrator throughput efficiency of approximately 93 percent. Potential future activities to further develop the technology include high temperature, high power throughput tests, antireflective coating tests, and additional material characterization and interaction tests.

This work was done by Wayne A. Wong and Steven M. Geng of **Glenn Research Center** *and Robert P. Macosko and Charles H. Castle of the Analex Corporation. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17149.

Cold Flow Calorimeter

This apparatus can measure a rapidly varying heat-transfer coefficient.

Marshall Space Flight Center, Alabama

The cold flow calorimeter is an apparatus for measuring a possibly rapidly varying heat-transfer coefficient on a surface. The cold flow calorimeter includes (1) a small strain gauge bonded to a small, thin steel shim that is placed on the surface of interest and (2) a circuit that controls the electric power supplied to the strain gauge to keep the strain-gauge grid at a constant temperature [e.g., 150 °F (≈66 °C)]. The instantaneous value of the heat-transfer coefficient is deduced from the instantaneous power required to maintain the constant temperature. The heat-transfer coefficient measurable by use of this apparatus can range from values characteristic of natural convection to values as large as about 1,000 Btu/(ft·h·°R) [≈1.7 kW/(m·K).

In the original application for which this apparatus was conceived, there is a need to measure heat-transfer coefficients along an O-ring surface in a nozzle joint in a solid-fuel rocket motor. In this application, there is a gas path to the sealing O ring. The cold flow calorimeter makes it possible to determine the coefficient of transfer of heat from a confined gas jet to the sealing O ring. The measurement data obtained by use of the cold flow calorimeter can be used to verify solutions from computational fluid dynamics, determine spreading factors, and increase the accuracy of predictions of the transfer of heat to an O ring to which there is a confined gas path.

This work was done by Ed Mathias and John Shipley of Thiokol Corp. for **Marshall Space Flight Center**. *For additional information, please contact Thiokol Corp. at (435) 863-2268.*

MFS-31463

Methodology for Tracking Hazards and Predicting Failures

This methodology can increase safety and reliability while reducing costs in all industries.

John F. Kennedy Space Center, Florida

The Continuous Hazard Tracking and Failure Prediction Methodology (CHTFPM) is a proactive methodology for gathering and analyzing information about a system in order to prevent accidents and system failures. The proactivity of the CHTFPM places it in contrast to conventional formal inductive and deductive hazard-analysis methodologies, which are limited in their effectiveness, in that they do not provide real-time information on whether the conditions in a system are becoming hazardous and could lead to a system malfunction: the conventional methodologies basically provide feedback on hazards after accidents have happened. The CHTFPM could be applied to advantage in almost all industries.

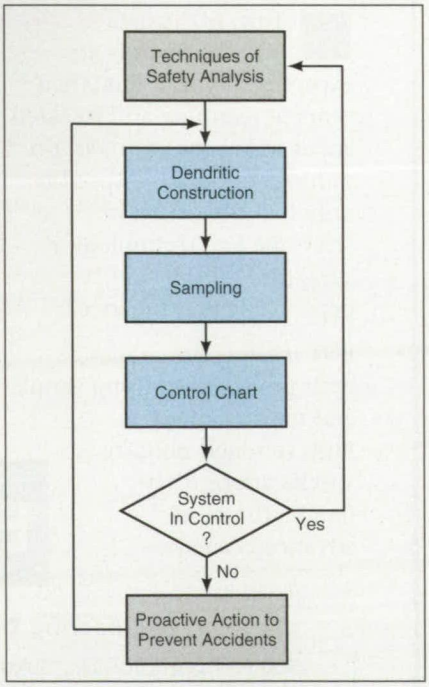
The CHTFPM involves the use of techniques from the arts of work sampling and control charting. With respect to a given system, random sampling is performed in order to detect and observe conditions, called "dendritics," that could result in accidents or unacceptable risks. The collected data are then used to generate an abstract data control chart. On the basis of the pattern of the control chart, the system is said to be "under control" (in essence, safe and thus not to be disturbed) or else "out of control," in which case it is investigated for the potential emergence of hazards from the observed conditions. The results of the investigation can provide guidance for steps to be taken to ameliorate the hazardous conditions to keep the system safe.

The steps in the evaluation and correction of a system according to the CHTFPM (see figure) are the following:

1. Define the dendritics by use of the established techniques of preliminary hazard analysis (PHA), fault-tree analysis (FTA), system safety analysis (SAA), system hazard analysis (SHA), failure mode and effects analysis/critical items list (FMEA/CIL), Pareto analysis, problem reporting and corrective action (PRACA), and/or safety checklists.
2. Develop the random-sampling scheme.
3. Construct the control chart from the samples.
4. Develop a mathematical model.
5. Test the control-chart observations for actual or potential "out of control" conditions.
6. Take appropriate action to prevent or eliminate any "out of control" condition.

Step 1 is the fundamental to everything else in the CHTFPM: the effectiveness of the CHTFPM depends on the identification of the dendritics for sampling in a given system. Regarding the techniques used in step 1:

- PHA can give the analyst both the necessary introduction of the system and an initial assessment of risk, identification of safety-critical areas, and evaluation of hazards.
- The emphasis on conditions, instead of events, is the single most compelling feature of the FMEA for dendritic construction.
- The CIL, derived from the FMEA, is useful for ensuring that the most critical items are factored into dendritic construction.
- FTA can contribute to understanding of interactions among components in the system. The single most important tool for dendritic construction is the FMEA.



Information About a System is gathered by sampling in a prescribed manner, the information is analyzed to detect hazards, and corrective action is taken.

The sampling feature makes CHTFPM a cost-effective tool for dynamically analyzing and tracking a system for dendritics. The sampling can be performed in conjunction with other routine job functions. Sample data are used to design a control chart for use in ensuring that the system remains within an acceptable range (between the control limits); or, in other words, that it does not shift "out of control." The more representative the sample is of the process in the system, the easier it is to detect shifts.

A major problem in the CHTFPM is to choose the size and frequency of samples. In general terms, the solution must be a compromise among considerations of the cost of sampling, the loss associated with running the process out of control, and the occurrence of various system shifts attributable to natural variability (essentially, background noise) or to assignable causes (e.g., machinery malfunctions or operator errors). A process that is operating with only natural variability is said to be in statistical control. A system operating in the presence of assignable causes is said to be "out of control." The control chart provides an effective means of detecting assignable causes, identifying currently problematic areas, and predicting future problematic areas. By providing information regarding the tendency of the system, the control chart indicates when the system tends to become hazardous, facilitating the implementation of corrective steps.

This work was done by Rolando Quintana of the University of Texas for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

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P ❑ Power/Energy
B ❑ Bio/Medical
J ❑ Consumer Product Manufacturing
Q ❑ Industrial Machinery & Equip.
A ❑ Aerospace
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Z ❑ Other *(specify):*

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3 **Your engineering responsibility is:** *(check one)*

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B ❑ Manage a Project Team
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4 **Your job functions are:** *(please check all that apply)*

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Estimating Heterodyne-Interferometer Polarization Leakage

Correction for the nonlinearity contributed by polarization leakage can be made in real time.

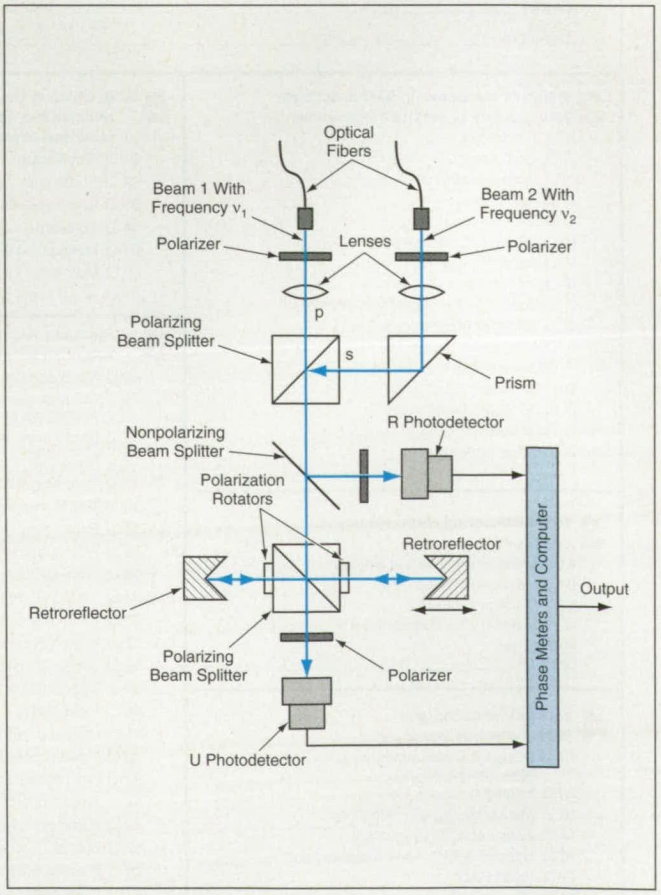
NASA's Jet Propulsion Laboratory, Pasadena, California

A method of estimating and correcting for the effect of polarization leakage on the response of a heterodyne optical interferometer has been devised. In a typical application in which a heterodyne interferometer is used as a displacement or length gauge, the effect of the polarization leakage is a nonlinearity that typically gives rise to an error of the order of 1 nm in the displacement or length. By use of the present method, it should eventually be possible, in principle, to reduce the error to the order of 10 pm or less. The technique is primarily computational and does not require any additional interferometer hardware. Moreover, the computations can be performed on almost any modern computer in real time.

The figure schematically depicts a typical heterodyne interferometer. The interferometer utilizes two laser beams with frequencies ν_1 and ν_2 that differ by a known small amount (typically, $|\nu_1 - \nu_2|$ is of the order of 1 to 100 kHz). Beams 1 and 2 are p- and s-polarized, respectively, in the reference frame of two polarizing beam splitters. Polarizers, polarization rotators, and a nonpolarizing beam splitter are used, along with the polarizing beam splitters, to separate and combine the beams at several junctions along the light path. The beams are made to interfere with each other at two photodetectors called the "reference" (R) and the "unknown" (U) photodetector, respectively. Ideally, all of the s-polarized light that arrives at the lower beam splitter makes one and only one round trip along the lower horizontal interferometer arm between two corner-cube retroreflectors, and then impinges on the U photodiode.

The difference-frequency outputs of the two photodetectors are the desired heterodyne signals. Small variations in the distance between the two retroreflectors are what one usually seeks to measure. In the ideal case, one could compute these displacements precisely from variations in the difference between the phases of the heterodyne signals from the two photodetectors. In practice, the phase measurement is degraded by noise and by systematic effects caused by imperfections in the interferometer optics. The major systematic source of error in the phase measurement is polarization leakage; that is, impingement, on the U photodetector, of (1) a small portion of the s-polarized light that passes directly through the lower polarizing beam splitter without taking the round trip between the retroreflectors and (2) another small portion of the s-polarized light that takes two or more round trips.

This polarization-leakage phase error (ε) is what gives rise to the nonlinearity in the interferometer response. The present method of estimating ε is based partly on the fact the polarization leakage is small and that ε is much less than 1 radian (as it is in cases of practical interest). A mathematical analysis shows that ε is a periodic function of ideal single-round-trip phase (ψ), and that given the aforementioned as-



A **Typical Heterodyne Optical Interferometer** is subject to polarization leakage, which introduces a phase error and a corresponding nonlinearity into its response.

sumptions, it can be approximated by the following equation:

$$\varepsilon(\psi) = A\cos(\psi) + B\sin(\psi) + C\cos(2\psi) + D\sin(2\psi) + \ldots,$$

where A, B, C, and D are parameters to be determined in a calibration procedure summarized in the next paragraph. In order to suppress the nonlinearity to the 10-pm level, the dominant parameter in this equation must be determined to one part in 100, while the other parameters may be determined to lesser accuracy, depending on their relative amplitudes.

One of the retroreflectors is mounted on a piezoelectric transducer that can be driven by a suitable voltage to displace the retroreflector along the interferometer arm. The calibration procedure involves the use of a triangular waveform at a typical frequency of a few hertz to induce an oscillatory displacement that spans a useful number (typically ≈10) of phase cycles so that the periodic ε component of the uncorrected phase measurement becomes recognizable. The uncorrected phase measurements are sampled, filtered, and otherwise processed to extract A, B, C, and D. Then the instantaneous corrected phase measurement (which should now be a closer approximation of the desired phase ψ) is given by

$$\psi_{\text{corrected}} = \psi_{\text{uncorrected}} - \varepsilon(\psi_{\text{uncorrected}}),$$

where $\varepsilon(\psi_{\text{uncorrected}})$ is calculated by substitution of the appropriate quantities in the above equation for $\varepsilon(\psi)$.

This work was done by Alex Abramovici and Randall Bartman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

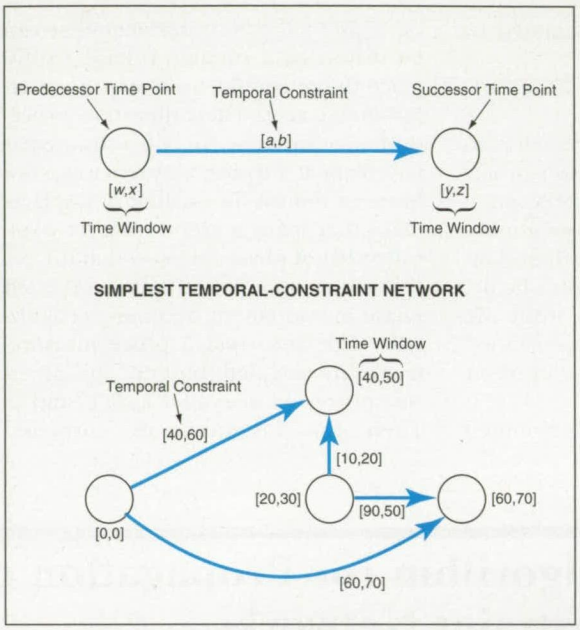
NPO-20906

An Efficient Algorithm for Propagation of Temporal-Constraint Networks

The computational cost is much less than in prior algorithms.

NASA's Jet Propulsion Laboratory, Pasadena, California

An efficient artificial-intelligence-type algorithm for the propagation of temporal constraints has been devised for incorporation into software that performs scheduling and planning of tasks in real time. This algorithm checks for temporal consistency and computes time windows of time points within temporal-constraint networks, which are often used in scheduling and planning. A C++-language computer program that implements the algorithm has been devised for incorporation into the control software of the Mission Data System of NASA's Jet Propulsion Laboratory. The algorithm and program



These **Simple Temporal-Constraint Networks** illustrate the basic principle of predecessor and successor time points joined by temporal constraints [*a*,*b*] = [minimum interval, maximum interval].

could also be applied to industrial planning and scheduling problems.

For the purpose of this discussion, "time point" signifies the nominal or planned time of occurrence of a specified event in, or state of, the system (e.g., a spacecraft or a production line) that is the subject of the planning and scheduling effort. A temporal-constraint network is equivalent to a graph, the nodes of which represent time points and the lines of which represent temporal constraints. The simplest such network (see figure) contains one predecessor and one successor time point that are required to be separated by a time interval of not less than *a* and not more than *b*. In forward propagation in this network, one would endeavor to update the time window of the successor point to be consistent with the time constraint and the time window of the predecessor point; similarly, in backward propagation in this network, one would endeavor to update the time window of the predecessor point to be consistent with the time constraint and the time window of the successor point.

The present algorithm involves iterations of forward and backward propagation; each iteration consists of a forward sweep followed by a backward sweep. Each sweep starts the propagation of temporal constraints from a subset of time points. During the propagation, the algorithm updates the time window at each time point by use of all its incoming temporal constraints in a forward sweep or all of its outgoing temporal constraints in a backward sweep. A data structure denoted a propagation queue is used to store time points, the successors or predecessors of which are to be updated next in a forward or backward sweep, respectively. Once the time window of a time point has been updated and all its incoming (or outgoing) temporal constraints have been used, that time point is placed in the propagation queue.

A forward sweep starts from a set of time points that have no predecessors. These time points are put in the propagation queue, then the sweep proceeds until the queue is empty. The backward sweep starts from a set of time points that have no successors, and then proceeds similarly to the forward sweep. It is assumed that there are no cycles (time-constraint paths that begin and end at the same time point) so that the algorithm will not enter an infinite loop during a sweep. The algorithm performs as many iterations as are needed until either (1) there is no window left to be updated or (2) a window of negative length is created. In case (1), the

final windows of all time points are considered to have been computed and the network is considered temporally consistent. In case (2), the algorithm returns the message to the effect that the network is temporally inconsistent.

The great advantage of this algorithm, relative to a prior temporal-constraint-propagation algorithm, is its computational efficiency and thus computational speed, and storage saving. The prior algorithm requires $O(N^3)$ number of arithmetic operations and $O(N^2)$ amount of memory [where $O(x)$ signifies proportionality to a quantity of the order of x and N is the number of time points in a temporal-constraint network]. In contrast, the present algorithm requires only $O(N)$ number of arithmetic operations and $O(N)$ amount of memory.

This work was done by John Z. Lou of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*
NPO-21098

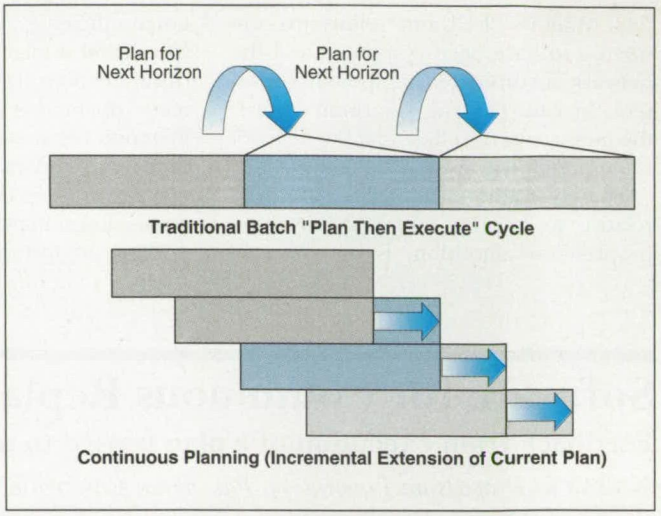
Software for Continuous Replanning During Execution

Feedback from execution of a plan is used to update the plan continuously.

NASA's Jet Propulsion Laboratory, Pasadena, California

Continuous Activity Scheduling Planning Execution and Replanning (CASPER) is a computer program for automated planning of interdependent activities within a system subject to requirements, constraints, and limitations on resources. Now at the prototype stage of development, CASPER was conceived to enable a robotic exploratory spacecraft to perform onboard, autonomous planning and replanning of scientific observations and other functions in response to diverse unanticipated phenomena that could include unknown or changing environmental conditions, equipment failures, and errors in mathematical models used in planning. On Earth, CASPER could be adapted to use in scheduling operations of production lines and other complex systems.

CASPER implements a concept of continuous planning integrated with execution, in contradistinction to the traditional concept of batch planning followed by execution. In traditional batch planning, time in the planned system is divided up into a number of relatively long planning horizons. When one nears the end of the current horizon, one projects what the state of the system will be at the end of execution of the current plan. The planning algorithm is then invoked with (1) a new set of goals for the next time horizon and (2) the projected end-of-execution state as the initial state for the next horizon. In this batch approach, planning is usually considered an off-



Batch-Planning and Continuous-Planning Algorithms differ in their ability to respond to unforeseen circumstances. In continuous planning, the plan is updated at relatively small increments of time to keep the plan as up to date as possible.

line process that entails considerable computation, and there is significant delay from the instant when the planning algorithm is invoked to the instant when the algorithm issues a new plan. In the event of a disruption (caused, for example, by an equipment failure or an inaccurate projection of the initial state) it could be necessary to stop execution of the current plan and put the system in a safe reduced operational mode for a considerable amount of time until a new batch plan is generated. On the other hand, if a fortuitous event occurs (e.g., a planned activity is completed ahead of schedule), it may not be possible to take advantage of the opportunity thus created because it would take too long to respond with a new batch plan.

In traditional batch planning (see figure), a planning algorithm is presented with goals and an initial state. In CASPER, the planning algorithm is presented with a current set of goals, a current plan, a current state, and a model of the expected future state. At any time, the planning algorithm can be called upon to update the goals, current state, or planning horizon (at increments of time much smaller than those of batch planning) in response to an unexpected event or simply in response to the passage of time. The replanning cycle comprises the following steps:

1. Changes to the goals and the initial state are posted to the plan.
2. The effects of the changes are propagated through the current plan projections, and resulting conflicts (if any) are identified.
3. Iterative plan-repair subalgorithms are invoked to eliminate conflicts and make the plan appropriate for the current state and goals. It is these subalgorithms that make it possible to update the plan incrementally (nearly continuously) during execution in response to changing conditions and unforeseen events.

This work was done by Russell Knight, Steve Chien, Robert Sherwood, Gregg Rabideau, Darren Mutz, Tara Estlin, Forest Fisher, and Barbara Engelhardt of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Information Sciences category.*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-20972.

Surface-Launched Explorers for Reconnaissance/Scouting

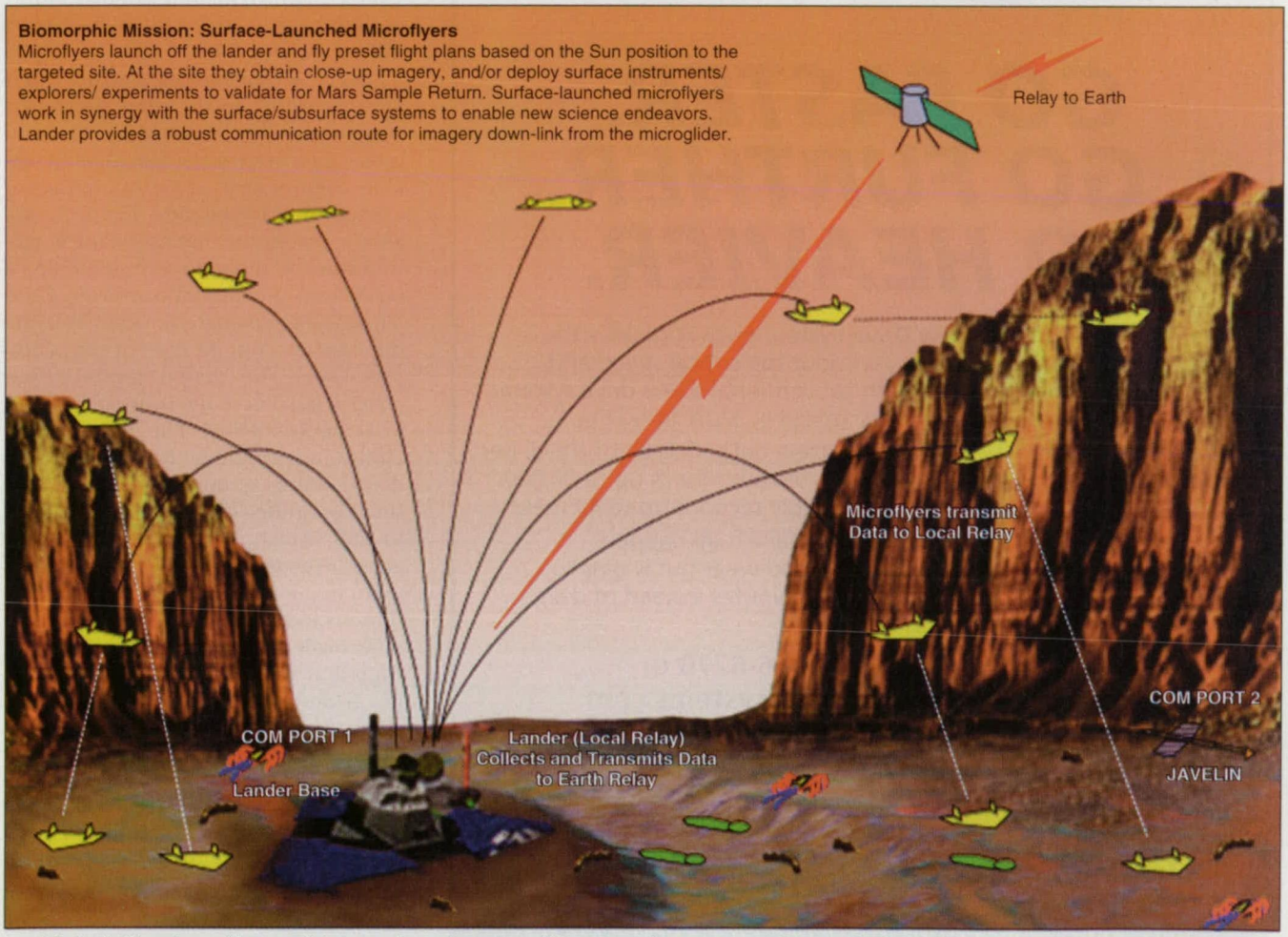
Efficiency of robotic exploration would be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

Small, instrumented, expendable robotic aircraft and projectiles have been proposed for use in scouting for targeted new sites by providing closeup images with ~10-cm resolution, covering large distances ~1 to 10 km quickly and allowing reconnaissance to enable sample return. Denoted microflyers or surface-launched explorers (SLEs), the proposed robotic aircraft and projectiles were conceived especially for use in the exploration of Mars and possibly other distant planets. SLEs could also be adapted to such terrestrial uses as military reconnaissance, exploration of hostile terrain (e.g., volcanoes, steep cliffs, or glaciers), surveying hazardous-waste sites, and searching for victims of earthquakes.

This class of SLEs enables biomorphic missions — hybrid missions which utilize surface assets and aerial assets synergistically to achieve new scientific endeavors along with deploying biomorphic explorers. Biomorphic explorers and related concepts have been described in several previous articles in *NASA Tech Briefs*, the most relevant being "Biomorphic Explorers" (NPO-20142), Vol. 22, No. 9, (September 1998), page 71; "Earthwormlike Exploratory Robots" (NPO-20266), Vol. 22, No. 6, (June 1998), page 11b; "Insectile and Vermiform Exploratory Robots" (NPO-20381), Vol. 23, No. 11, (November 1999), page 61; "Biomorphic Gliders" (NPO-20677), Vol. 25, No. 4 (April, 2001); and "Seed-Wing Flyers for Exploration" (NPO-20676), Vol. 26, No. 1, (January, 2002), page 47.

SLEs could include guided projectiles, gliders, electrically powered airplanes and helicopters, and possibly other robotic flyers; specific types, designs, and combinations of SLEs would be tailored to specific applications. In a typical application, the SLEs would be launched from a lander/base station/mobile explorer



Small Robotic Aircraft would transmit images of terrain and possibly sensory data to an exploratory robotic vehicle (lander).

(see figure) or from a spacecraft, aircraft, or other vehicle that delivered the lander to the exploration site. The means of launching could be as diverse as the SLEs themselves: they could include rockets, balloons, pneumatic devices, or spring mechanisms, for example.

An SLE could carry a small video camera, sensors, and a radio transmitter to send images of the terrain to the lander. The images could help in quickly identifying sites of scientific interest to be explored in more detail and allow identifying hazards and slopes and access the area for its potential for sample return. The images could also be helpful in planning the path of other surface/ subsurface explorers across the terrain.

An SLE could be designed to safely land after following a ballistic trajectory in the low gravity of Mars. After landing, the SLE could continue to function as a scientific instrument: For example, it could analyze surface and/or subsurface soil and use its remaining energy to transmit the analytical data to the lander/mobile explorer. One or more SLEs designed to survive impact would resemble javelins and would be launched in such a way that, like javelins, they would embed themselves in the ground at the far ends of their trajectories; these SLEs would serve as radio beacons to aid navigation by the other SLEs as secondary communication ports in addition to the primary port on the lander. The lander serves as the local relay to send the data back to Earth via the orbit.

This work was done by Sarita Thakoor and Terry Martin of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Machinery category.*
NPO-20871

Firmware for a Small Motion-Control Processor

NASA's Jet Propulsion Laboratory, Pasadena, California

A C-language computer program implemented as firmware controls the operations of a microprocessor on a 3-by-1-inch (approximately 76-by-25-mm) motion-control circuit board denoted a widget board. The firmware implements a serial communication interface according to the inter integrated circuit bus (I^2C) standard by use of an interrupt-driven state machine to enable communication to occur during execution of commands. The firmware also controls the operation of a motion-control integrated-circuit chip, a serial analog-to-digital converter, a serial digital-to-analog converter, and the digital input/output lines of the microprocessor. The digital input/output control portion of the firmware offers a masking capability. The firmware includes a provision for dynamically downloading, to the widget board, of a small program (limited to 12 lines and to 256 bytes). A microexecutive program executes the downloaded program in a loop, with the option of continuous looping. The execution of the downloaded subprogram can be interrupted at the user's request. The widget firmware includes a set of more than 48 commands, 24 control operations, and 24 query operations.

This program was written by Issa Nesnas of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Software category.*
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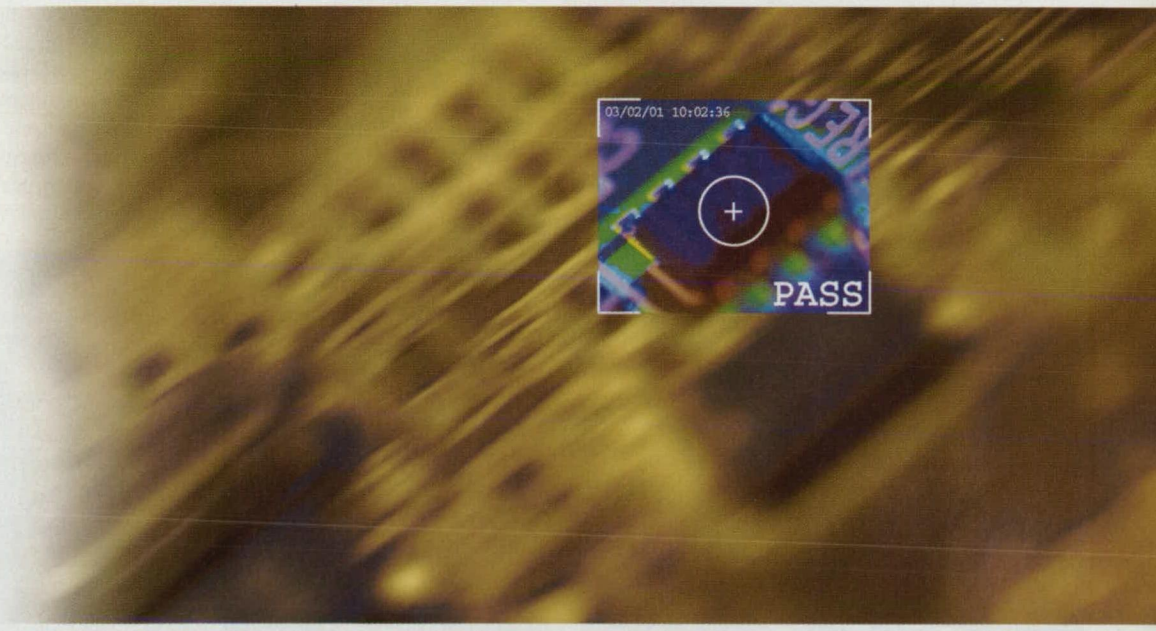

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Gear Bearings and Gear-Bearing Transmissions

Planetary transmissions could be simpler, cheaper, and more rigid.

Goddard Space Flight Center, Greenbelt, Maryland

Gear bearings are conceptual mechanical components so named because they function as gears and as roller and/or thrust bearings. Gear bearings will be essential components of the next generation of compact, large-mechanical-advantage gear drives.

Figure 1 shows a working gear-bearing transmission with 70/1 gain in a 1.25-in.-diameter-by-0.75-in. (3.18-cm-diameter-by-1.91-cm) package. Gear bearings exist as spur- or helical-gear variants of two basic types: roller gear bearings and phase-shifted gear bearings. For the sake of brevity, only spur-gear variants are described here; suffice it to say that the principles of operation of the helical-gear variants are similar.

Figure 2(a) depicts selected aspects of roller spur-gear bearings and a partial planetary assembly containing roller spur-gear bearings. The diameter of the roller portion of each roller spur-gear bearing equals the pitch diameter of the spur-gear portion. The gear teeth are crowned at the roller end, such that the apogee of the crown on each tooth lies at the roller diameter/pitch diameter: This arrangement provides thrust-bearing strength as well as matching of speeds and, hence, efficiency.

The planetary assembly would inherently hold itself together, without bracing by other structures. For example, if a planetary roller gear bearing shown in the cross-sectional view were pushed downward, the axial sliding of its teeth with respect to the ring- and sun-gear teeth is stopped by the abutment of the planetary roller against the crowns of the ring-gear teeth. When the same planetary gear is pushed upward, its axial sliding is blocked by abutment of the planetary teeth against the ring roller. Similar interactions prevent axial sliding of the sun roller gear bearing beyond the limits imposed by tooth/roller contacts between the sun and planetary roller gear bearings.

Figure 1. A **Working Gear-Bearing Transmission** shown here has a 70/1 speed reduction in a 1.25-in.-diameter-by-0.75-in. (3.18-cm-diameter-by-1.91-cm) package.

An additional advantage is that by enforcing the desired relative locations of gears more precisely, the incorporation of the rollers increases (relative to simple spur gears) the accuracy of meshing of spur-gear teeth. At the same time, the gears act as highly efficient and precise cages and carriers for the rollers. The net result is a superior, simpler, and relatively inexpensive assembly.

Figure 2(b) presents a simple example of a phase-shifted spur-gear bearing. The

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Exclusively from HD Systems, the Harmonic Planetary® HPG Series provides the motion control and design engineer with a planetary gearhead that reduces backlash to less than 1 arc-min. This level of backlash is maintained for the life of the gear.

This design is made possible by developing a ring gear that can flex in the radial direction, while maintaining high torsional stiffness. The result is a planetary gearhead that provides consistently low backlash, high efficiency, and high output speeds.

This planetary gearhead is available in 3 frame sizes from 60mm to 120mm. Rated torque ranges from 53 in-lb to 956 in-lb. Peak torque ranges from 496 in-lb to 5753 in-lb. Gear Ratios 5:1 to 45:1. Flange or shaft output available.

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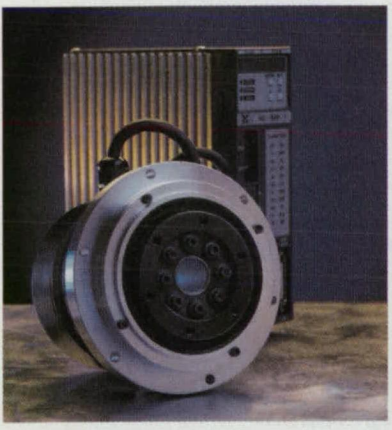

NEW, Hollow Shaft Actuators

The FHA Series of actuators features a through-bore up to 45mm in diameter and provides high torque and exceptional positioning accuracy. This performance is achieved in a compact design using a patented "S" tooth harmonic drive gear coupled to a DC brushless pancake motor with integral electronic commutation and a high resolution encoder. Rated torque up to 1730 in-lb and positional accuracy better than 1 arc-minute can be achieved. The FHA Series is available in five frame sizes, ranging from 128 to 300mm in diameter, and 116 to 248mm in length.

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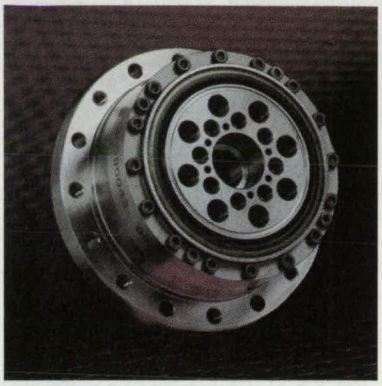

The CSF-2UH series high torque gearheads use HD Systems' patented "S" tooth that delivers more than twice the torque, twice the life, and twice the torsional stiffness when compared to conventional Harmonic Drive Gearing. Positional Accuracy is better than 1 arc-min. The CSF-2UH series is available in 10 frame sizes with rated torque ranging from 48 in-lb to 8400 in-lb and peak torque ranging from 310 in-lb to 42,000 in-lb. Gear Ratios 50:1 to 160:1.

The CSF series uses a rigid cross roller bearing to support its output flange. This combination allows the gearhead to be extremely compact while providing high axial, radial, and moment load capacities. Easily interfaced with a servo motor, these zero backlash, high accuracy gear systems are ideal for indexing tables, robots, and factory automation equipment. Flange or shaft output available.

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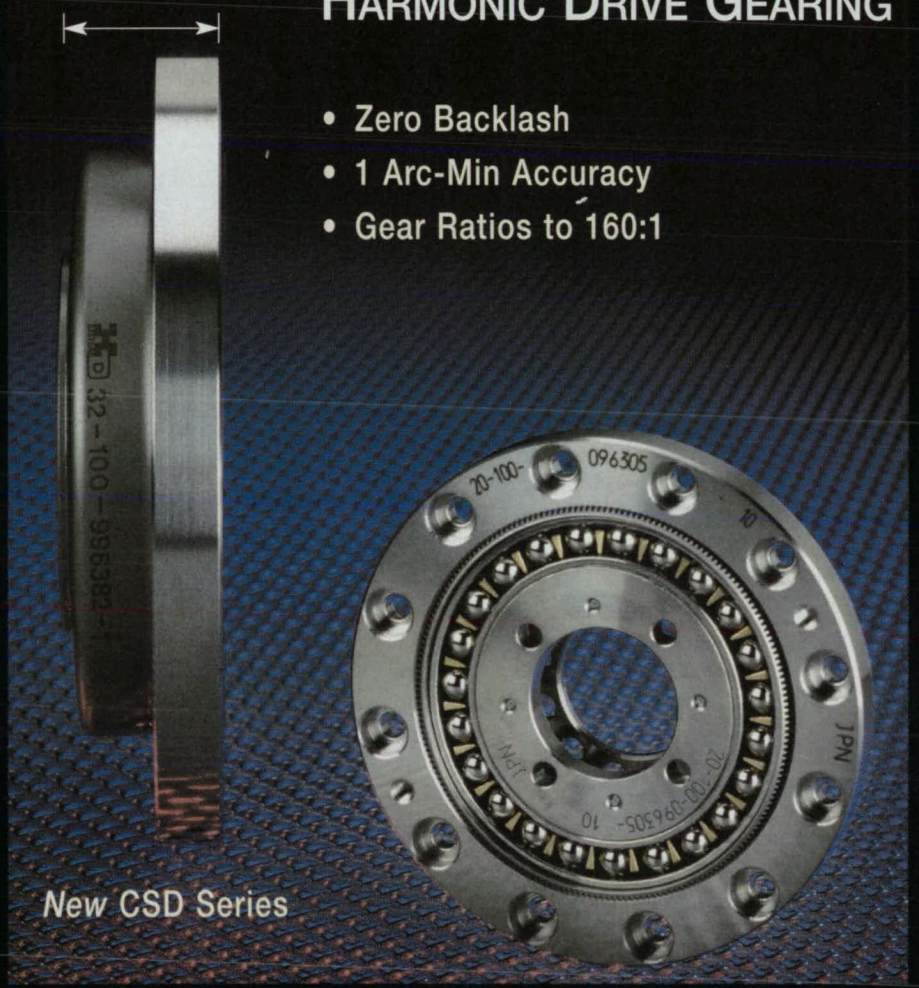

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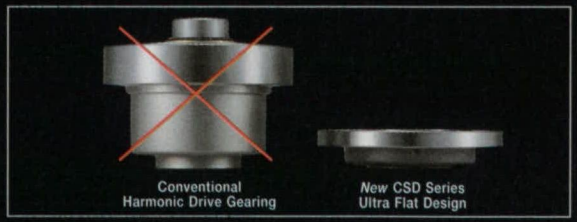

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teeth in the upper and lower halves are shifted angularly, relative to each other, by precisely a half-tooth interval. This gear bearing meshes with a copy of itself. The upper and lower teeth are beveled and partly interdigitated where they meet. The contact between the beveled surfaces of the upper and lower teeth provide a thrust-bearing capability in a manner similar to that of the contact between the crowns and rollers of the roller gear bearings. Moreover, a planetary assembly containing phase-shifted gears holds itself together in a manner similar to that of an assembly containing roller gear bearings as described above.

This work was done by John M. Vranish of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Mechanics category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center ; (301) 286-7351. Refer to GSC-14207.

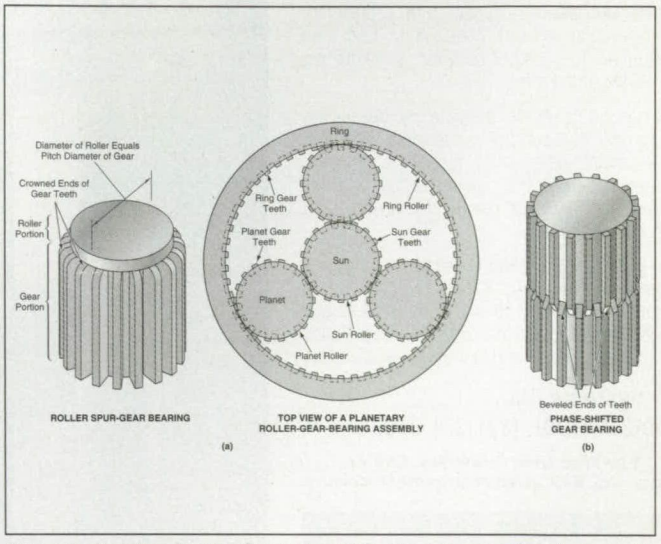


Figure 2. **Gear-Bearing Configurations:** (a) roller spur-gear bearings would offer advantages, relative to simple spur gears and bearings, for the operation of planetary gear assemblies. (b) A phase-shifted gear bearing could mesh with an identical twin and would offer advantages similar to that of the roller spur-gear bearing depicted in (a).

Linear Dynamometer With Variable Stroke and Frequency

Stroke length and frequency can be adjusted continuously during operation.

John H. Glenn Research Center, Cleveland, Ohio

An improved linear dynamometer has been developed for testing linear alternators that are to be used to convert mechanical power to electrical power in free-piston Stirling-cycle engines. Both the frequency and the length of the stroke of this dynamometer can be varied continuously, even during operation; consequently, the dynamometer can be used to fully map the capabilities of a linear alternator throughout its service envelope (its operational range as defined on a plot of limiting stroke length versus frequency) in a single test.

The dynamometer includes a balanced twin-throw eccentric crank mechanism that converts the rotary motion of a drive motor to the desired linear motion of a plunger that consti-

tutes the moving part of the linear alternator under test. To eliminate vibration on the alternator stator, the crank mechanism also imparts an equal and opposite linear motion to a balance mass that is equal to the mass of the plunger. The position of the drive-motor-and-crank assembly along a line perpendicular to the linear-stroke axis can be adjusted hydraulically to vary the eccentricity of the crank and thereby vary the length of the stroke. A compensating mechanism maintains the center of the plunger stroke with the center position of the stator. The frequency of the stroke is controlled simply by controlling the speed of the drive motor.

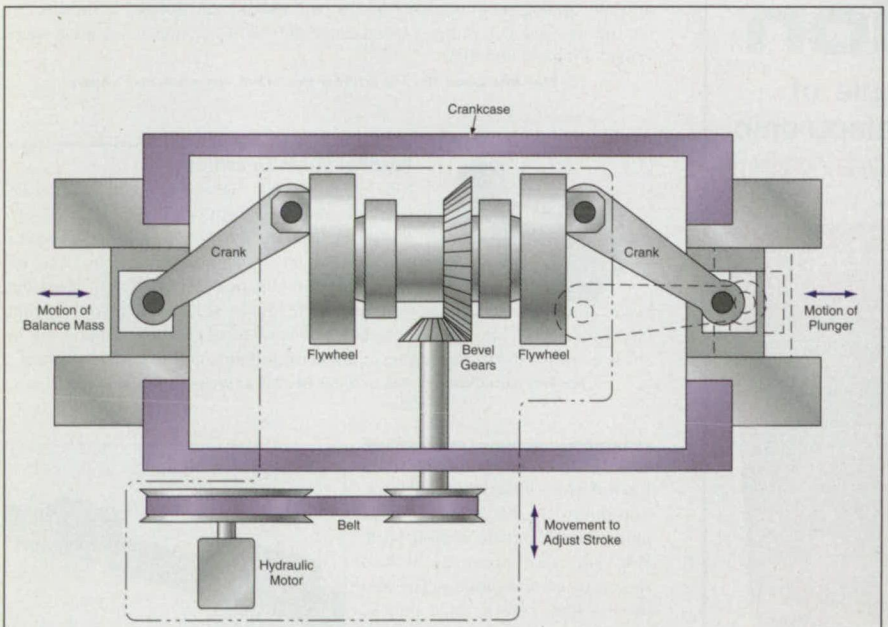
The dynamometer comprises four main interconnected modules: the crankcase with drive mechanism (see figure), the power pack, the operator console, and the load bank. The crankcase is an assembly of steel plates formed into a closed box enclosing the drive mechanism described above. A scavenging pump maintains a negative gauge pressure in the crankcase to minimize leakage of oil at the joints. The power pack contains a 125-horsepower (93-kW) motor that drives a compound pump that provides (1) pressurized oil for controlling the stroke and driving the hydraulic motor and (2) pressurized oil from a separate supply for lubrication.

A magnetostrictive sensor measures the displacement of the plunger. An encoder on the shaft of the hydraulic motor measures the speed. A programmable-logic controller compares the displacement and speed readings with set-point values of speed and stroke commanded via the operator console and actuates solenoid-operated servovalves to adjust the flows of oil accordingly.

The power generated by the linear alternator is dissipated in the load bank, which is a commercially available unit that presents a purely resistive load of 3 ohms and up, with selectable resistance to absorb up to 30 kW at up to 300 V. The load resistors in the load module are cooled by a fan. The load module is equipped with meters that read potential, current, frequency, and power, and with fault indicators and lockouts for fan failure, overtemperature, and overvoltage. The potential and current readings from the load bank are displayed on the operator console along with the frequency, the stroke length, the stroke-control position, and the reaction force of the stator in the alternator under test.

This work was done by George Yarr of Clever Fellows Innovation Consortium, Inc., for **Glenn Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com/tsp*** *under the Machinery category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16951.



The **Length of the Stroke of This Dynamometer** is adjusted by adjusting the vertical position (and thus the eccentricity) of the balanced twin-throw eccentric crank mechanism.

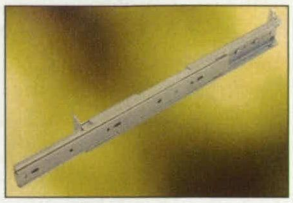
NEW PRODUCTS

Tachometers and Encoders

Phoenix America, Fort Wayne, IN, has introduced a line of tachometers and encoders for determining average or instantaneous speed and direction in industrial applications. The units also can be used as incremental encoders for determining rotational position. The tachometer/encoders feature permanent magnet target wheels with mounting options such as press fit hubs and set-screw hubs. They also include two solid-state digital output switches mounted in quadrature. The two output channels can be used to determine speed and direction.

For Free Info Circle No. 740 or Enter No. 740 at www.nasatech.com/rs

Ball Bearing Slide



The Model 2907 ball bearing slide from Accuride International, Santa Fe Springs, CA, measures 0.38" wide and can be mounted in 1U to 4U racks. It carries loads up to 100 pounds, and full extension plus two inches of over-travel allow ensure access to the front, back, and sides of the chassis. A lever disconnect provides chassis removal and reinsertion. The slide is available in even lengths from 12" to 30". A bracket kit adapts to a range of EIA rail configurations including square, tapped, and through holes.

For Free Info Circle No. 741 or Enter No. 741 at www.nasatech.com/rs

Motor Drives

Anacon Systems, Mountain View, CA, offers the EagleDrive™ Series of variable frequency drives (VFDs) that connect to worldwide electrical supplies for variable speed control of single-phase AC induction motors (EagleDrive1™ Series) and three-phase AC induction motors (EagleDrive3™ Series). All models feature a pushbutton keypad, variable or constant torque, selectable inverter switching frequencies, three digital and one analog programmable inputs, and galvanically isolated control terminal inputs. EagleDrive1 has a speed range of 0-100 Hz; EagleDrive3 has a speed range of 0 to 30,000 RPM.

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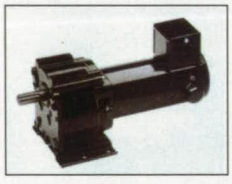

Parallel Shaft Gearmotor

The M4000 GIL200 Series permanent magnet DC parallel shaft gearmotor from RAE Corp., McHenry, IL, is rated to 300 in/lbs with speeds up to 350 RPM and voltages ranging from 12 to 180 VDC. The units feature TENV design, reversible design, double shield ball bearing construction, class F insulation, hardened steel gears, and an oil-filled gearbox. Applications include conveyor drives, packaging equipment, robotics, and material handling.

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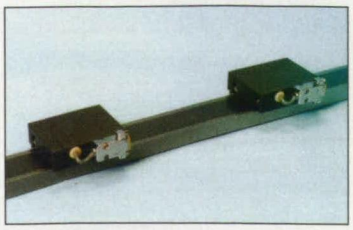
Direct Drive Linear Actuators



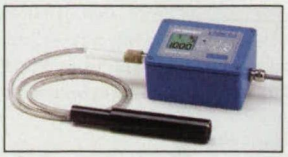
IntelLiDrives, Philadelphia, PA, has introduced the BB series of linear motors that eliminate friction, backlash, and wear problems of lead screws, racks, and pinions. The two-piece system consists of a passive, magnet-free, stationary platen that serves as a linear guideway, and a moving forcer with built-in roller bearings. All bearings are magnetically preloaded. Forces range from 5 to 15 pounds, and travel length ranges to 80". The forcers are capable of velocities of 60 in/sec and can be supplied with the company's I-Drives microstepping indexers and drivers.

For Free Info Circle No. 744 or Enter No. 744 at www.nasatech.com/rs

New on the MARKET

Thermometer/Transmitter

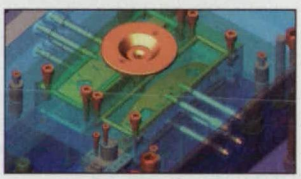
The OS1592 infrared fiber optic thermometer/transmitter from OMEGA Engineering, Stamford, CT, measures temperature ranges to 4500°F and provides dual analog outputs electrically isolated from the DC power supply input. The main electronics are in a NEMA-4 rated aluminum housing with a local backlit LCD, built-in relay, and a four-position programmable keypad. The system has accuracy of 1% of reading and 25 msec response time. **For Free Info Circle No. 711 or Enter No. 711 at www.nasatech.com/rs**



Rugged Portable PC

The DEWE-4000-IPC Industrial Portable Computer from Dewetron, Charlestown, RI, features an ATX motherboard, allowing up to eight full-size, full-length PCI cards to be added to the system. The standard display is 18.1" TFT, is available with a touch screen, and runs at resolutions up to 1280 x 1024. The video interface is an AGP card with up to 128 MB of VRAM for moving video. **For Free Info Circle No. 716 or Enter No. 716 at www.nasatech.com/rs**

Mold Design Software



Manusoft Corp., Waconia, MN, has introduced IMOLD for SolidWorks that enables design of plastic injection molds. It performs core/cavity separation, mold layout, gating and slide/lifter design, and runner, cooling, and ejection system design. It provides an Intelligent Fastener System feature that fastens all the mold plates, inserts, and components together, and generates assembly drawings. Using the SolidWorks environment, the software creates 3D, solids-based mold bases. **For Free Info Circle No. 712 or Enter No. 712 at www.nasatech.com/rs**

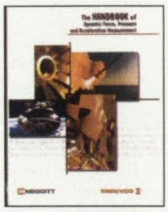
FEA Software

Noran Engineering, Los Alamitos, CA, has added a nonlinear, tension-only shell element to its NE/Nastran V8.1 solver. The element acts as a normal shell in tension and reduces to a shear panel in compression. The interface works with existing models using standard quadrilateral and triangular plate elements and properties. **For Free Info Circle No. 714 or Enter No. 714 at www.nasatech.com/rs**

Measurement and Control

National Instruments, Austin, TX, has released LabVIEW 6.1 graphical development software for test, monitoring, and control applications. Users can control their measurement and automation applications from any location using LabVIEW 6.1 via a standard Web browser. Users can import and export XML-formatted data to integrate virtual instruments with other Web or database applications in their enterprise. **For Free Info Circle No. 713 or Enter No. 713 at www.nasatech.com/rs**

New LITERATURE



Measurement Reference

Endevco Corp., San Juan Capistrano, CA, has published a measurement handbook for dynamic force, pressure, and acceleration. The handbook covers measurement topics such as conceptual and dynamic models for transducers, the properties of silicon and piezoelectrics, the characteristics of time-varying signals, measurement system design, calibration, and data interpretation. **For Free Info Circle No. 705 or Enter No. 705 at www.nasatech.com/rs**

Data Converters

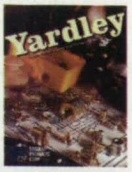
Signal Processing Technologies, Colorado Springs, CO, has updated its product selection guide to include analog-to-digital converters, digital-to-analog converters, video line drivers, track-and-hold amplifiers, and comparators. Product charts can be referenced to specifications including resolution, sample rate, power dissipation, linearity, and package information for each product. **For Free Info Circle No. 706 or Enter No. 706 at www.nasatech.com/rs**

Electronic Enclosures

A 67-page catalog from Bud Industries, Willoughby, OH, highlights electronic enclosures, including accessories, brackets, cabinets, card racks, chassis, communication products, die-cast aluminum boxes, large cabinet racks, open racks, plastic boxes, and small metal enclosures. The catalog helps users select the proper enclosure, accessories, and components needed to package their product. **For Free Info Circle No. 707 or Enter No. 707 at www.nasatech.com/rs**

Magnet Design

A handbook from Magnet Applications, Horsham, PA, offers information on magnet design including shaping/forming processes such as injection molding and compression bonding, the use of Finite Element Analysis (FEA) modeling as an aid in design, and magnet material characteristics and their impact on manufacturing applications. **For Free Info Circle No. 708 or Enter No. 708 at www.nasatech.com/rs**



Fastening Inserts

Yardley Products Corp., Yardley, PA, has released a 21-page catalog detailing Molded-In, Pressed-In, Sharp-Sert®, Trisert®, Intro-Sert®, Fiber-Sert®, Quick-Sert®, and Bi-Sert® inserts. The catalog features product specifications including applications, base materials, metric thread size, length, and tolerance. **For Free Info Circle No. 709 or Enter No. 709 at www.nasatech.com/rs**

Ball Bearing Slides

Accuride International, Santa Fe Springs, CA, has released a brochure of solutions for industrial and electronic design problems using ball bearing slides. The brochure includes ball bearing and friction slides for a range of industries and applications. **For Free Info Circle No. 710 or Enter No. 710 at www.nasatech.com/rs**

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411	412	413	414	415	416	417	418	419	420
421	422	423	424	425	426	427	428	429	430
431	432	433	434	435	436	437	438	439	440
441	442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459	460
461	462	463	464	465	466	467	468	469	470
471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490
491	492	493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508	509	510
511	512	513	514	515	516	517	518	519	520
521	522	523	524	525	526	527	528	529	530
531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568	569	570
571	572	573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588	589	590
591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610
611	612	613	614	615	616	617	618	619	620
621	622	623	624	625	626	627	628	629	630
631	632	633	634	635	636	637	638	639	640
641	642	643	644	645	646	647	648	649	650
651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670
671	672	673	674	675	676	677	678	679	680
681	682	683	684	685	686	687	688	689	690
691	692	693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708	709	710
711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730
731	732	733	734	735	736	737	738	739	740
741	742	743	744	745	746	747	748	749	750
751	752	753	754	755	756	757	758	759	760
761	762	763	764	765	766	767	768	769	770
771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790
791	792	793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808	809	810
811	812	813	814	815	816	817	818	819	820
821	822	823	824	825	826	827	828	829	830
831	832	833	834	835	836	837	838	839	840

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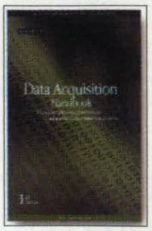

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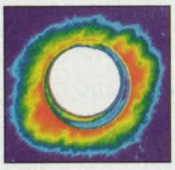

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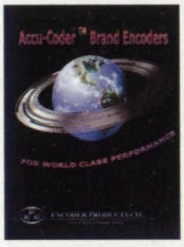

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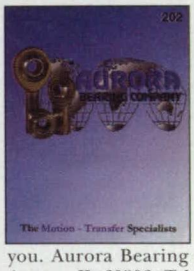

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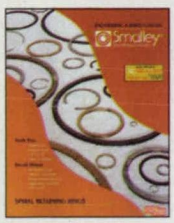

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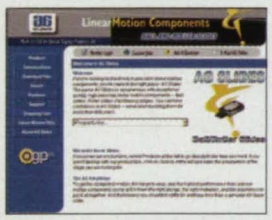

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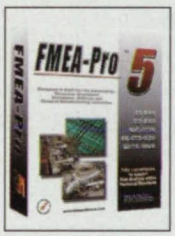

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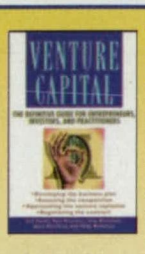

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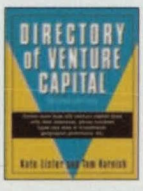

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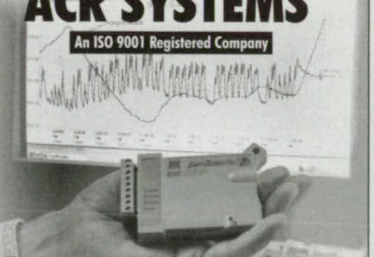

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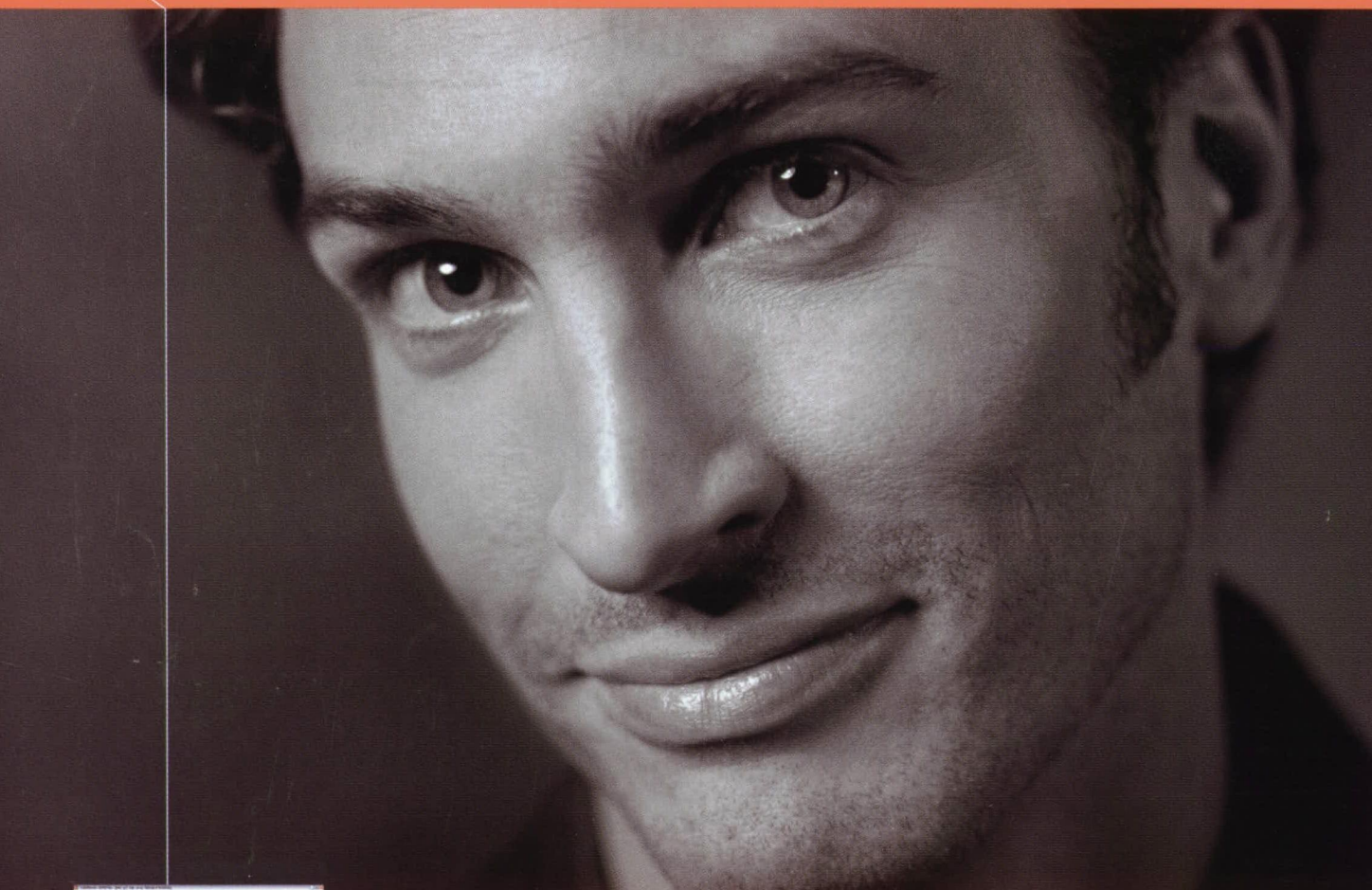

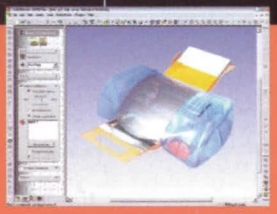

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